Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-82

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11 February 1997

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

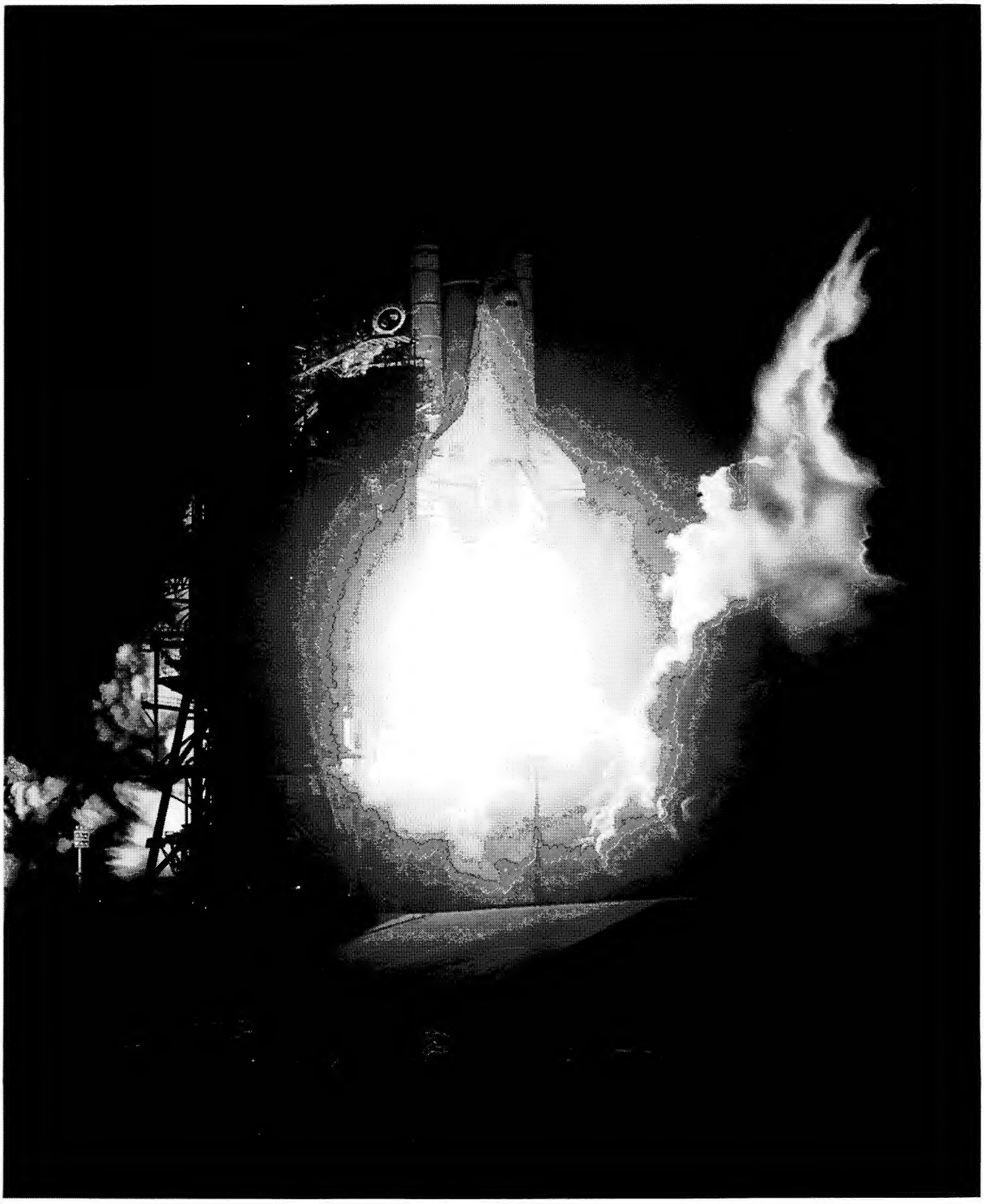

Photo 1: Launch of Shuttle Mission STS-82

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 10 February 1997. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-103 Discovery (22nd flight), ET-81 (LWT 74), and BI-085 SRB's. There were no significant vehicle or launch pad anomalies.

With the February/winter launch and a liftoff time of 3:55 a.m. local, weather conditions were predicted to be unseasonably warm with strong winds. Based upon weather predictions the day before launch, the SURFICE computer program calculated the surface temperature on the upper LH2 tank would not drop below 32 degrees F until the launch window opened. Therefore, no significant ice accumulation on the ET acreage was expected.

The vehicle was cryoloaded for flight on 10 February 1997. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. Although the ambient temperatures during cryoload were somewhat cooler than predicted, strong northwesterly winds prevented significant amounts of ice or frost from forming on the LO2 and LH2 tank acreage. There were no protuberance icing conditions outside of the established data base.

After the 3:55 a.m. (local) launch on 11 February 1997, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. All the T-0 umbilicals operated properly. There were no stud hang-ups. Overall, damage to the launch pad was minimal.

A total of 101 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission.

No ordnance fragments or frangible nut pieces fell from any of the other DCS while in the field of view. No stud hang-ups or frangible nut/ordnance debris was observed on any of the holddown posts.

Tape inadvertently left on the LH SRB aft booster just aft of the IEA adhered to the SRM case through tower clear. The tape, used during IEA closeout/ablator trimming, had been detected during the Pre-Flight Inspection, but after the Orbiter Weather Protection (OWP) platforms had been retracted. MRB approval to fly the tape rather than re-extending the OWP's was obtained.

OV-103 was not equipped to carry ET/ORB umbilical cameras. Handheld still photos of the ET after separation were taken by the flight crew. The photos revealed no significant anomalies.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums were in excellent condition. No MSA-2 debonds over acreage or fasteners were detected. All eight BSM aero heat shield covers had locked in the fully opened position, though the two outboard cover attach rings on the left frustum had been bent by parachute riser entanglement. There were no clear indications of aft skirt stud hole broaching or stud hang-ups on this flight (review of launch films support this finding). The holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally with the exception of HDP#4, where the plunger seating was obstructed by the frangible nut halves. This condition may have been the result of splashdown. Tape inadvertently left on the LH SRB aft booster just aft of the IEA during pre-launch processing was mostly intact.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-103 Discovery was conducted 21 February 1997 at the Kennedy Space Center on SLF runway 15. The Orbiter TPS sustained a total of 103 hits, of which 18 had a major dimension of 1-inch or larger. A comparison of these numbers to statistics from 66 previous missions of similar configuration indicates both the total number of hits and the number of hits 1-inch or larger were less than average.

The Orbiter lower surface tiles sustained 53 damage sites, of which 14 were larger than 1-inch long in size. The largest lower surface tile damage site was located on the left chine about midway between the nose gear door and the left main gear door. The site measured 2-inches long by ¼-inch wide by 1/16-inch maximum depth.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities with the exception of a 2-inch long piece of white RTV. Bent metal, approximately 1-inch in length by 1/4-inch wide, was visible on the trailing edge of a spacer between two bolt heads on the inside surface of the LO2 ET door near the forward outboard corner.

Damage to base heat shield tiles, attributed to SSME vibration/acoustics and exhaust plume recirculation, appeared somewhat more than usual. Two adjacent tiles close to SSME #1/#3 base mounted heat shields exhibited a cluster of seven large damage sites. A similar cluster of six damage sites spanning four tiles occurred in a mirror-image area outboard of the SSME #1/#2 base mounted heat shields. These two locations may be vibration/acoustic focal points. A base mounted heat shield tile at the SSME #2 4:00-5:00 o'clock position was missing a 4-inch by 2-inch by 1-inch deep corner piece. The opposite corner of this same tile sustained a 3-inch crack.

Tiles on the upper surface of the body flap near the outboard edges sustained greater than usual damage from downward firing RCS thrusters.

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be average in size and number. A somewhat unusual finding consisted of a cluster of 14 hits, including four larger than 1-inch, in the black-tiled area between windows #3 and #4. These damage sites are believed to be the result of impacts from FRCS thruster paper covers/RTV adhesive.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 10 February 1996 at 0700 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC Chief, ET/SRB Mechanical Systems
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J. Blue	USA - SPC ET Mechanical Systems
W. Richards	USA - SPC ET Mechanical Systems
M. Wollam	USA - SPC ET Mechanical Systems
G. Fales	USA - SPC ET Mechanical Systems
J. McClymonds	BNA - DNY Shuttle Aerodynamics
F. Foster	BNA - LSS Systems Integration
J. Cook	THIO - LSS SRM Processing
S. Otto	LMSO - LSS ET Processing
A. Howard	USA - Safety

3.0 LAUNCH

STS-82 was launched at 97:042:08:55:17.026 UTC (3:55 a.m. local) on 11 February 1997.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 10 February 1997. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-103 Discovery (22nd flight), ET-81 (LWT 74), and BI-085 SRB's. There were no significant vehicle or launch pad anomalies.

Tape was inadvertently left on the LH SRB aft booster just aft of the IEA. The tape, used during IEA closeout/ablator trimming, was detected during the Pre-Launch Inspection, but after the Orbiter Weather Protection (OWP) platforms had been retracted. MRB approval (IPR 82V-0262) to fly the tape rather than re-extending the OWP's was obtained.

With the February/winter launch and a liftoff time of 3:55 a.m. local, weather conditions were predicted to be unseasonably warm with strong winds. Based upon weather predictions the day before launch, the SURFICE computer program calculated the surface temperature on the upper LH2 tank would not drop below 32 degrees F until the launch window opened. Therefore, no significant ice accumulation on the ET acreage was expected.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 10 February 1997 from 1020 to 1150 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. Although the ambient temperatures during cryoload were somewhat cooler than predicted, strong northwesterly winds prevented significant amounts of ice or frost from forming on the LO2 and LH2 tank acreage. There were no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, particularly those areas not visible from remote fixed scanners, and to scan for unusual temperature gradients.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The F2U, R2U, R3D, and R4D RCS thruster covers were intact, but tinted green indicating small internal vapor leaks. Ice/frost and condensate had formed on SSME #1 and #2 heat shield-to-nozzle interfaces. Condensate was present on the SSME #3 heat shield-to-nozzle interface. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers averaged 52-57 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature supplied by THIO was 63 degrees F, which was within the required range of 44-86 degrees F.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a comparison to infrared scanner point measurements. As-built TPS thicknesses were used in the SURFICE data input along with real-time weather parameters. The program predicted ET surface temperatures would not drop below 38 degrees F. Only condensate, with no ice/frost accumulation, on the TPS acreage surfaces was expected during cryoload.

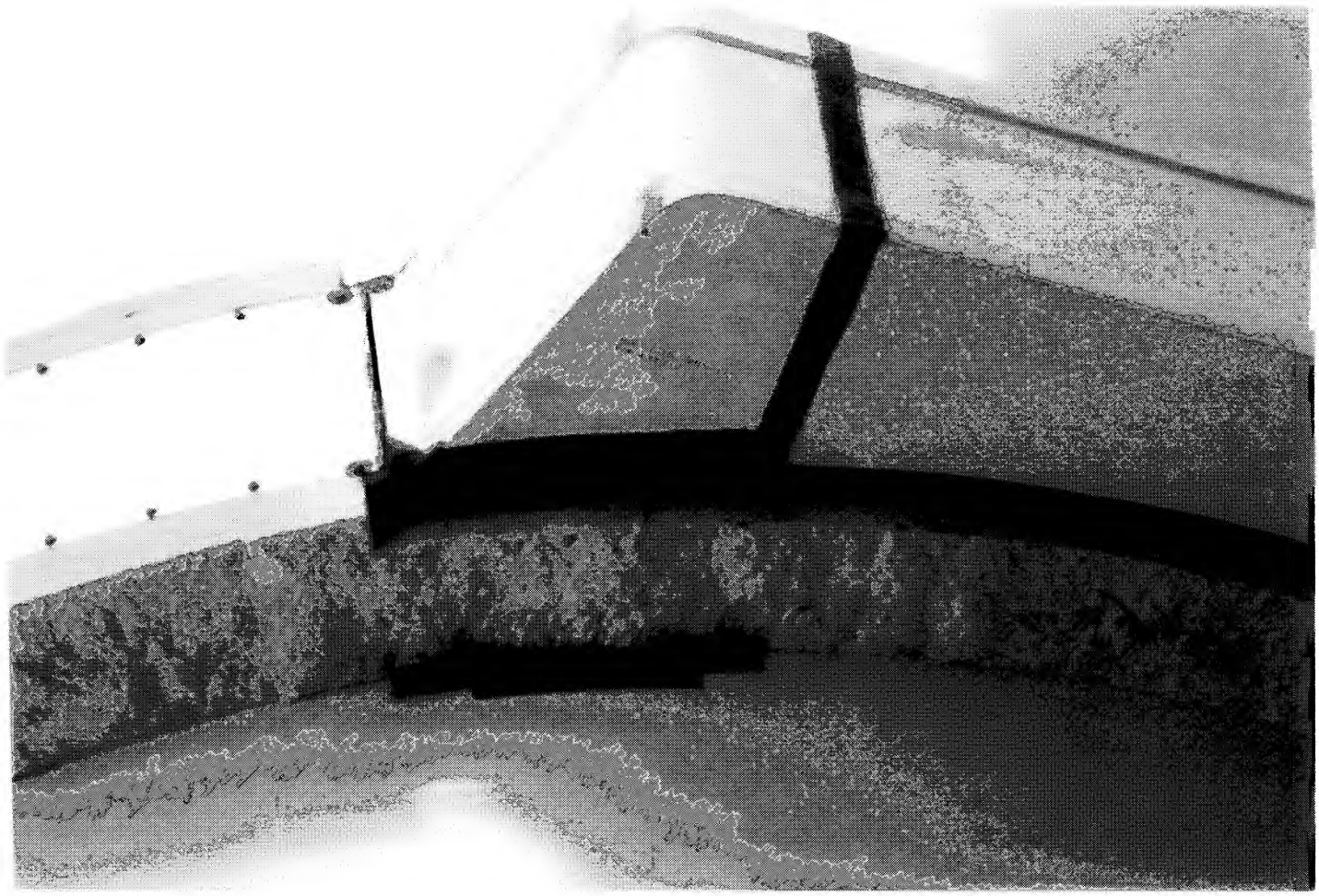


Photo 2: Tape Inadvertently Left on LH SRB Aft Booster

Tape was inadvertently left on the LH SRB aft booster just aft of the IEA. The tape, used during IEA closeout/ablator trimming, was detected during the Pre-Launch Inspection, but after the Orbiter Weather Protection (OWP) platforms had been retracted. MRB approval (IPR 82V-0262) to fly the tape rather than re-extending the OWP's was obtained.

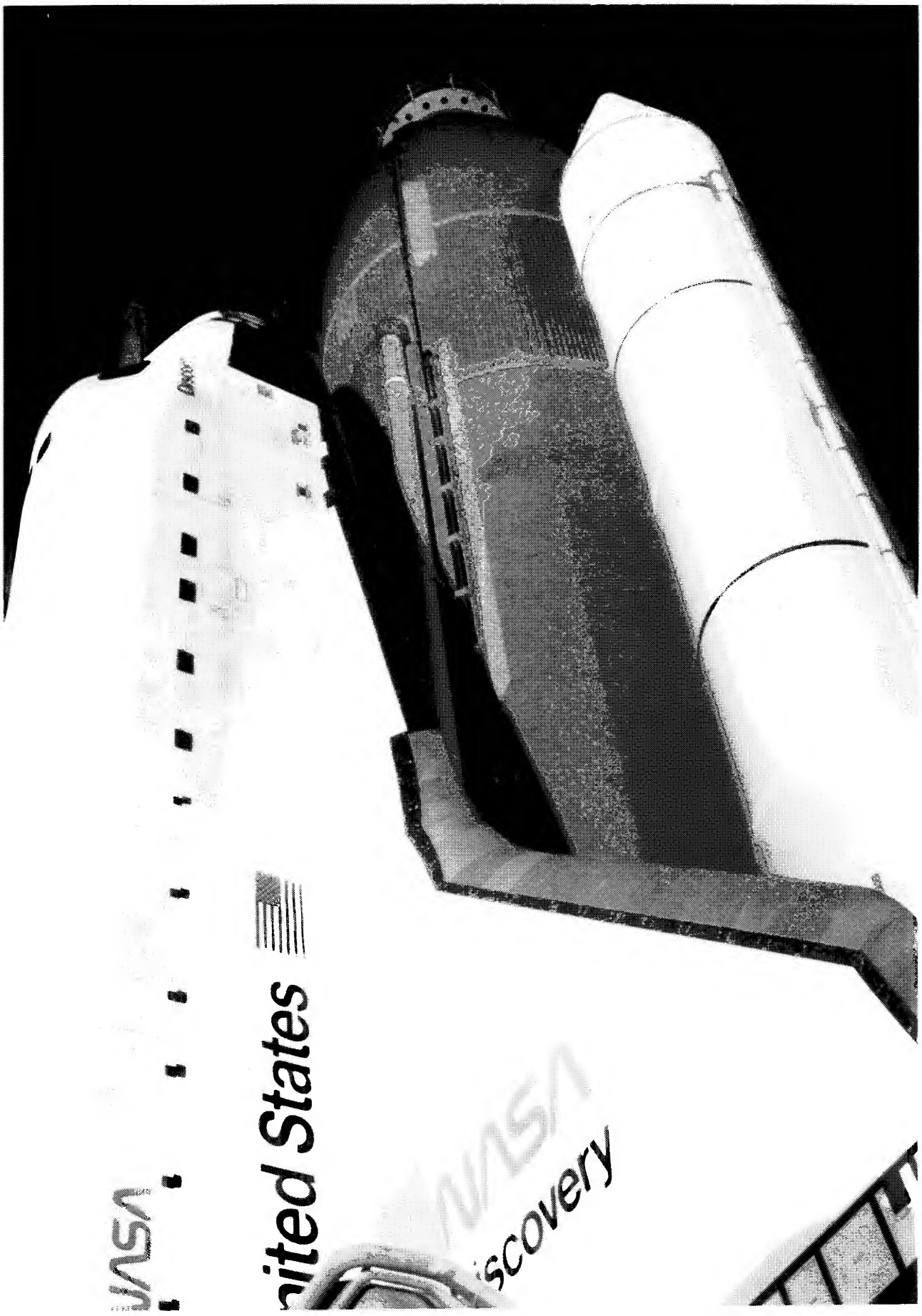


Photo 3: STS-82 Cryoloaded for Flight

OV-103 Discovery (22nd flight), ET-81 (LWT 74), BI-085 SRB's

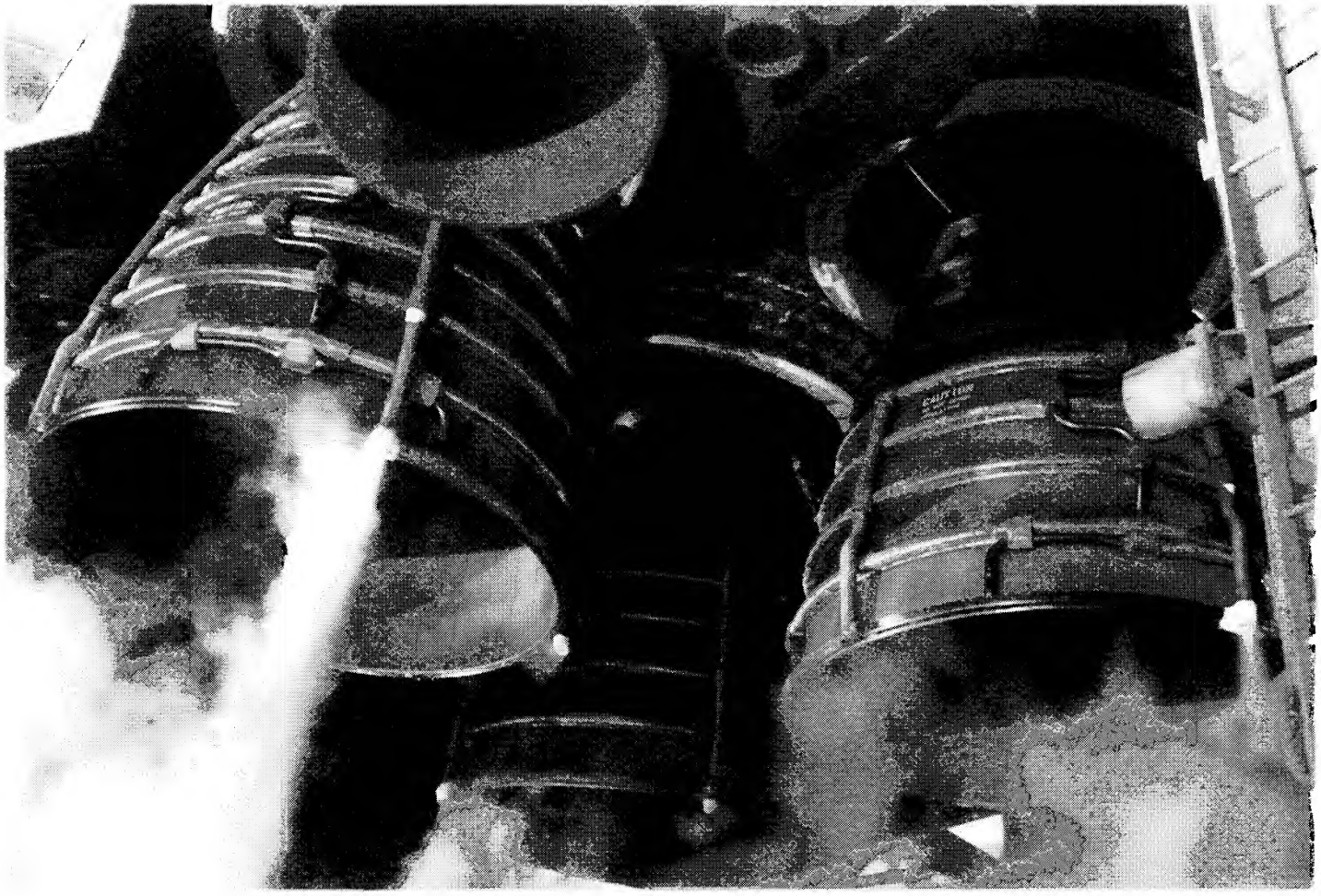


Photo 4: Ice/Frost and Condensate on SSME #2 Heat Shield-to-Nozzle Interface

The Final Inspection Team observed very light condensate, but no ice or frost accumulations, on the LO2 tank. TPS surface temperatures ranged from 42-48 degrees F.

The Intertank acreage exhibited no TPS anomalies. Ice/frost accumulation on the GUCP appeared typical. The average surface temperature of the Intertank TPS was 53 degrees F.

The Final Inspection Team observed moderate condensate, but no ice or frost accumulations, on the LH2 tank. TPS surface temperatures ranged from 39-48 degrees F. A small ice/frost ball had formed on the outboard bondline of the -Y bipod spindle housing closeout.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

An 3-inch long by ¼-inch wide stress relief crack had formed on the -Y vertical strut forward facing TPS. The presence of the crack was expected and acceptable for flight per the NSTS-08383 criteria.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical. A 1-1/2 inch diameter PDL repair on the aft surface of the umbilical cable tray was not flush (protruded slightly) with the surrounding TPS.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Smaller than usual ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch.

No leaks were observed on the GUCP or the LO2 and LH2 Orbiter T-0 umbilicals.

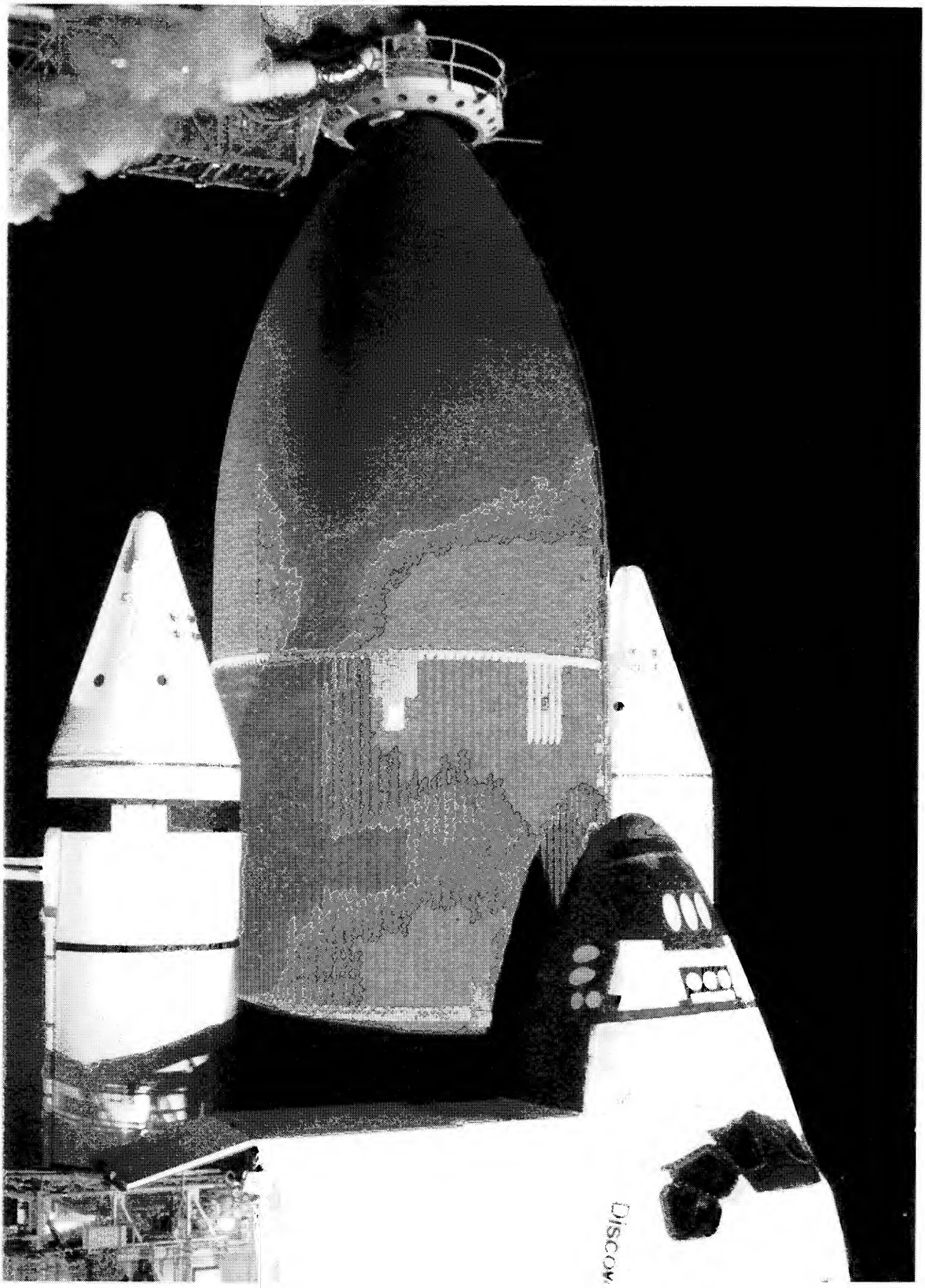


Photo 5: LO2 Tank and Intertank

The Final Inspection Team observed very light condensate, but no ice or frost accumulations, on the LO2 tank. TPS surface temperatures ranged from 42-48 degrees F.

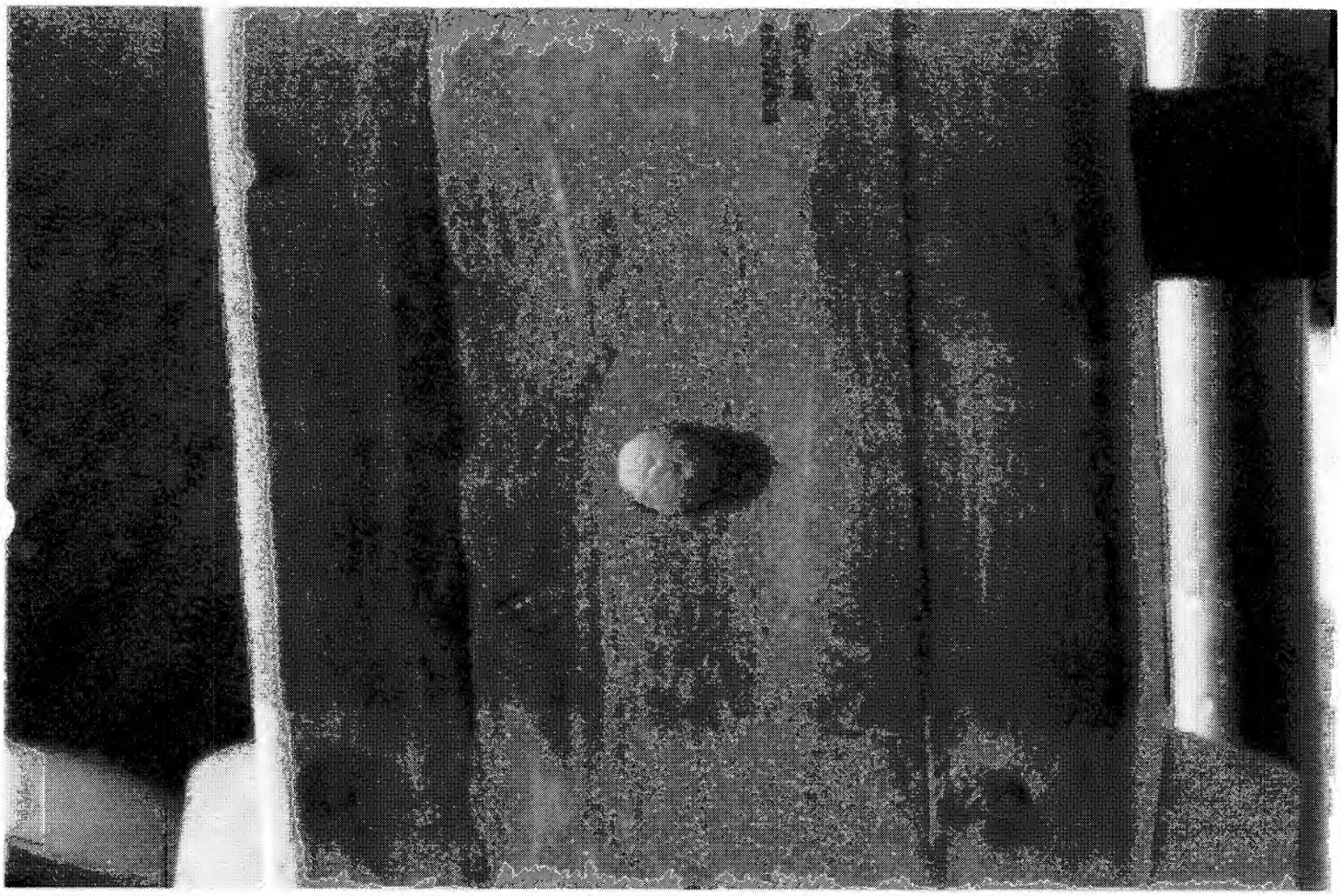


Photo 6: Protruding PDL Repair

A 1-1/2 inch diameter PDL repair on the aft surface of the umbilical cable tray was not flush (protruded slightly) with the surrounding TPS.

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of MLP-1, FSS, RSS, and Pad A was conducted on 11 February for 1.5 hours starting at Launch + 1.5 hours.

No flight hardware or TPS materials were found.

SRB Hold Down Post (HDP) erosion was typical. The reported Orbiter lateral accelerometer measurement of 0.18 g's indicated a probable stud hang-up. These have occurred on previous missions with lateral accelerations ranging from 0.14 to 0.31 g's. HDP film analysis and more detailed HDP/SRB aft skirt inspections determined there was no stud hang up.

The HDP blast covers closed properly. Aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage. A crack 25 feet long in the MLP raised deck ran from the RH SRB flame hole to a point near the topside MLP hatch. Width of the crack was as much as ¼-inch with an offset up to 1-inch.

The cap to a "gooseneck" connector west of the LH SRB flame hole was missing and located near the RSS trolley. Several other large pieces of facility debris were also located near the trolley including an OIS box cover.

A piece of aluminum measuring 8-feet long by 4-inches wide by ¼-inch thick found on the pad apron originated from the left APU enclosure side 4 wall on the RSS 107 foot level. The aluminum has been identified as wall siding flashing attached to a temporary wall, which replaced the primary wall damaged on the STS-81 launch. The siding was not visible in any of the high speed launch films and most likely shook loose from exhaust plume impingement as the vehicle cleared the tower.

The Tail Service Masts (TSM), Orbiter Access Arm, and Gox Vent Arm showed no visible indications of damage. TSM bonnets had closed properly.

The GH2 vent line was latched on the fifth of eight teeth of the latching mechanism. The ET GUCP had not been contacted by the retract lanyard. A section of handrail was blown from mounts next to the GUCP and was held to the structure by the kick plate only.

Miscellaneous facility straps and clamps were found on the pad apron and acreage.

Overall, damage to the pad appeared minimal.

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 83 films and videos, which included twenty-seven 16mm films, seventeen 35mm films, and thirty-nine videos, were reviewed starting on launch day.

An unusual flickering light or reflection on MLP side #2 just before SSME ignition probably originated from the OTV camera 009 light bank (E-1). Reflections from this flickering light were visible on the LH SRB aft booster during SSME startup (E-3, -4).

With the exception of Mach diamond formation (in the order 2-3-1), SSME ignition appeared normal (OTV-051, -070, -071). Free burning hydrogen drifted up to the OMS pods (OTV-070 and -071; E-16, -19).

Tile surface coating material was lost during ignition from two places on the base heatshield outboard of SSME #2 (E-17), one place on the -Y side of the SSME #3 heat shield (E-18), two places on the aft surface of the LH RCS stinger (E-20), and one place on the aft surface of the LH OMS pod (E-20).

SSME ignition caused pieces of ice to fall from the ET/ORB umbilicals. Several pieces of ice contacted the LH2 umbilical cavity sill and were deflected outward. No tile damage was visible (OTV-009 and -164).

An orange-colored GSE tile shim/spacer falling outboard of SSME #3 at 08:55:12.387 UTC appeared to originate from the base heat shield (E-17). Another orange-colored tile shim/spacer first appeared behind the LH OMS nozzle heat shield at 08:55:14.748 UTC and fell aft past SSME #1 without contacting flight hardware (E-20, -77).

A string of RTV adhesive with attached pieces of RCS paper cover fell from the R4D thruster at 08:55:17.912 UTC (E-17, -19).

Four pieces of ice were shaken loose from the LO2 feedline upper bellows during vehicle "twang", fell aft between the Orbiter and the ET, and eventually passed the right inboard elevon. A fifth piece of ice from the same bellows was shaken loose at liftoff (OTV 061 and OTV 054). No contact with the lower surface tiles was observed.

A light-colored object passed the upper surface of the right inboard elevon near T-0 (OTV 054).

High humidity caused the SRB exhaust plume shock wave to be momentarily visible immediately after T-0 (OTV 041, 048).

No stud hang-ups or frangible nut/ordnance debris was observed on any of the holddown posts.

Tape inadvertently left on the LH SRB aft booster just aft of the IEA adhered to the SRM case through tower clear (E-31 and E-40). The tape, used during IEA closeout/ablator trimming, had been detected during the Pre-Flight Inspection, but after the Orbiter Weather Protection (OWP) platforms had been retracted. MRB approval (IPR 82V-0262) to fly the tape rather than re-extending the OWP's was obtained.

Photo 7: SSME Mach Diamond Formation

SSME #2 Mach Diamond formed prior to SSME #3.

Photo 8: GSE Tile Shim

An orange-colored GSE tile shim/spacer falling outboard of SSME #3 appeared to originate from the base heat shield. Another orange-colored tile shim/spacer first appeared behind the LH OMS nozzle heat shield and fell aft past SSME #1 without contacting flight hardware.

A protuberance on the left wing upper surface near the trailing edge cast a short shadow from the light of the SRB exhaust plume just after liftoff. A search of design records and pre-launch photos showed the protuberance as a thermocouple instrumented tile (E-54, -63).

Most of the ET/ORB umbilical purge barrier material came loose and fell aft at the beginning of the roll maneuver. The purge barrier was visible at 08:55:26.990 UTC with a four foot long piece of tape at 08:55:27.659 UTC (E-52, -59).

Debris streaks occurred in the SSME exhaust plume during ascent (E-220).

Several light-colored particles, most likely pieces of instafoam from SRB aft skirt aft rings, fell along side the SRB exhaust plume during ascent at 08:55:38.896 UTC and 08:56:24-36 UTC (E-220, -223; TV-4).

Body flap movement (amplitude and frequency) was visible in film item E-212.

The SRB exhaust plume recirculation, which was exceptionally visible due to the night launch, appeared typical (E-208).

SRB separation appeared normal. Numerous pieces of slag were readily visible falling from the SRB plume during tailoff, as well as during and after separation (TV-13, -4; E-208, -212, -223).

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-103 was not equipped to carry umbilical cameras. Handheld photography by the flight crew consisted of twenty-nine still 35mm images. No significant anomalies were detected.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 17 films and videos, which included seven 35mm large format films and ten videos, were reviewed. The films were generally dark due to the pre-dawn lighting conditions.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was virtually simultaneous at approximately 3,000 feet from the runway threshold. The Orbiter stayed close to the runway centerline during rollout.

Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth. Rollout and wheel stop were uneventful.

No significant TPS damage was visible in the films.

Photo 9: ET On-Orbit

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-085 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAS Hangar AF on 13 February 1997.

Both frustums were in excellent condition. No TPS was missing and no debonds were detected over fasteners or acreage. Very little Hypalon paint had blistered. All eight BSM aero heat shield covers had locked in the fully opened position, though the two outboard cover attach rings on the left frustum had been bent by parachute riser entanglement.

The forward skirts exhibited no debonds or missing TPS. RSS antennae covers/phenolic base plates were intact and undamaged. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the frustum severance rings.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ETA ring, IEA, and IEA covers appeared undamaged from splashdown.

Tape inadvertently left on the LH SRB aft booster just aft of the IEA during pre-launch processing was mostly intact. The tape, used during IEA closeout/ablator trimming, had been detected during the Pre-Flight Inspection, but after the Orbiter Weather Protection (OWP) platforms had been retracted. MRB approval (IPR 82V-0262) to fly the tape rather than re-extending the OWP's had been obtained.

TPS on the external surface of both aft skirts was intact and in good condition. Internally, foam was missing and substrate exposed on the aft skirt aft rings.

There were no clear indications of aft skirt stud hole broaching or stud hang-ups on this flight (review of launch films support this finding). The holddown post Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally with the possible exception of HDP#4, where the plunger seating was obstructed by the frangible nut halves. This condition may have been the result of splashdown.

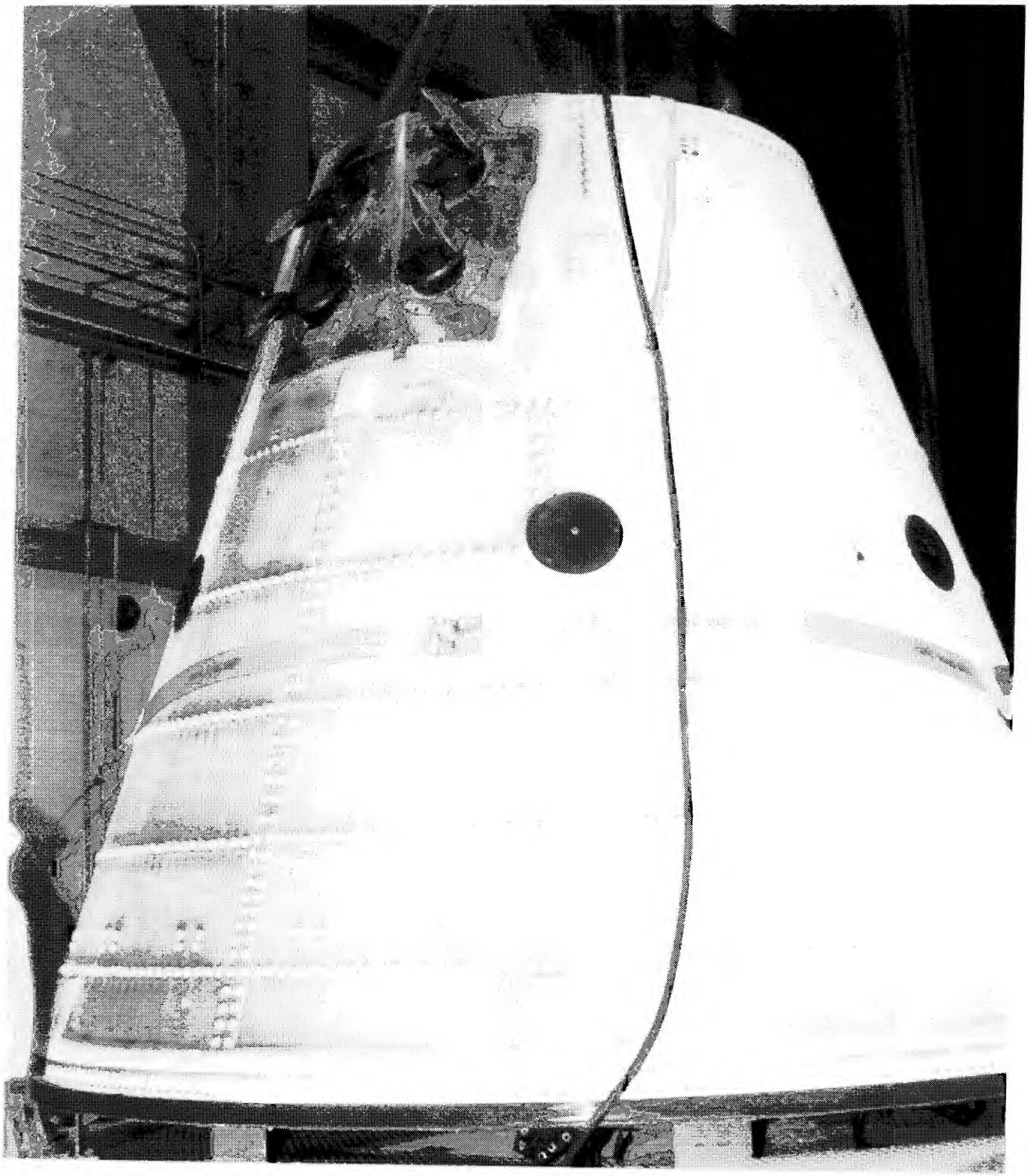


Photo 10: LH Frustum

Photo 11: RH Frustum

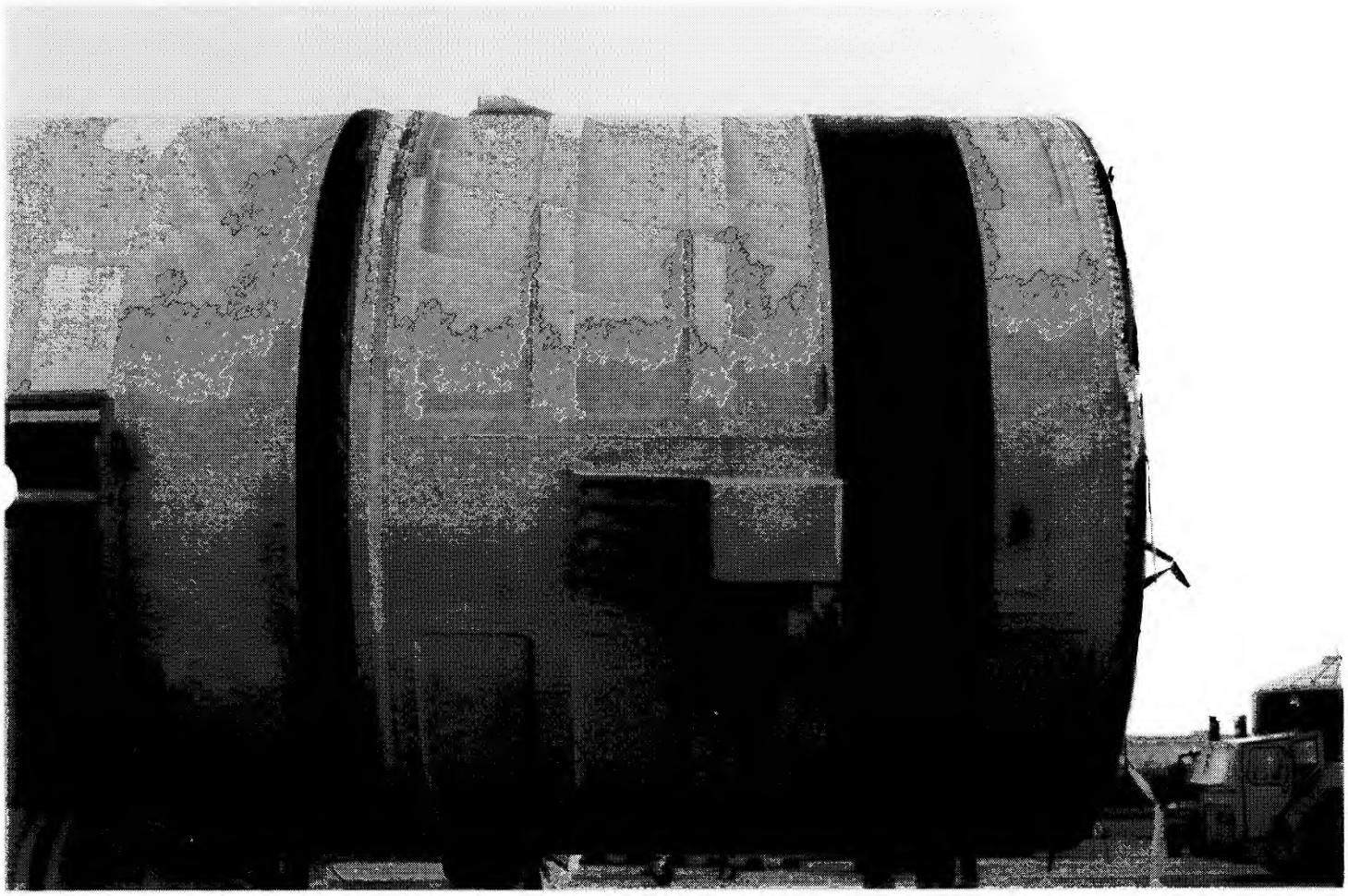


Photo 12: LH Forward Skirt

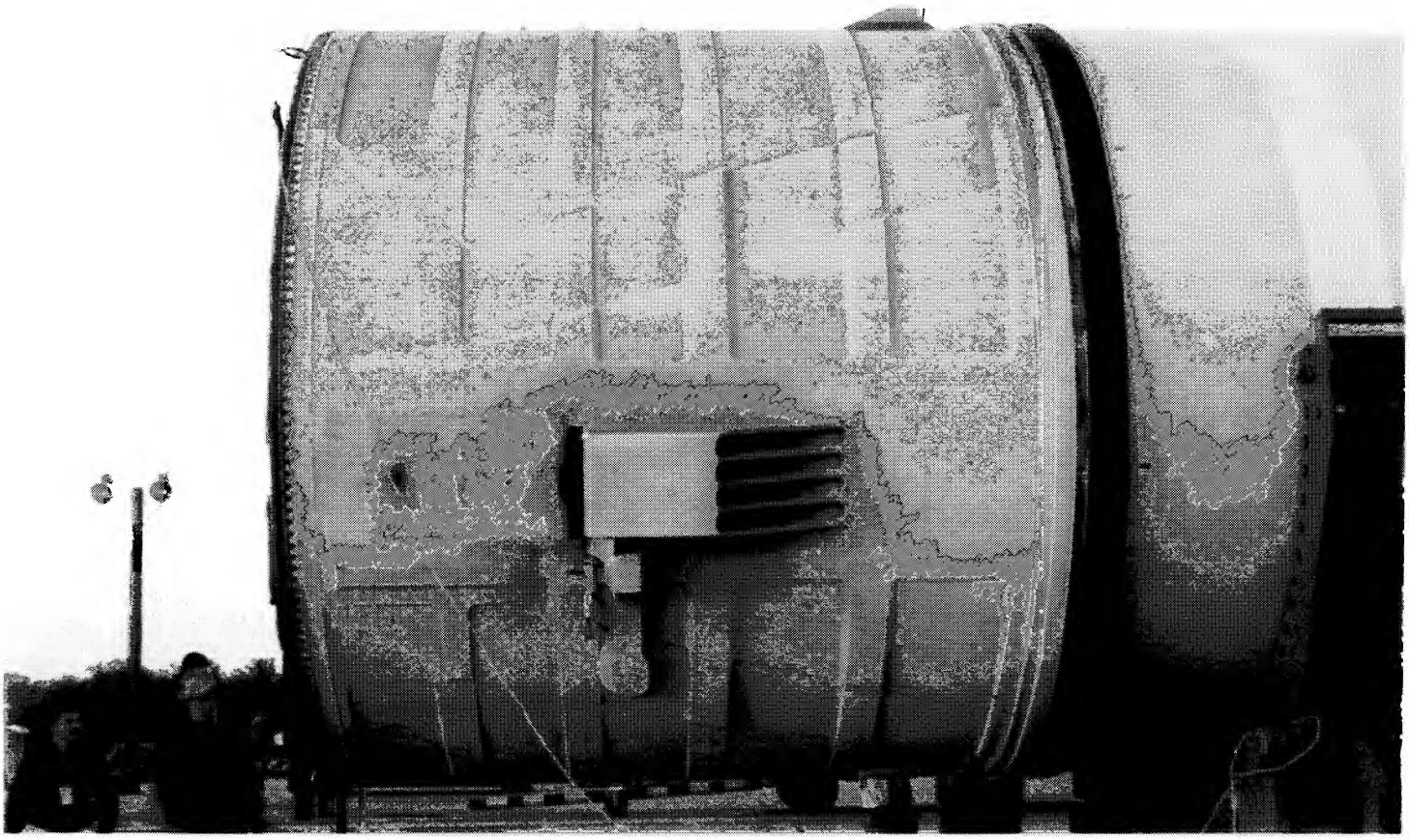


Photo 13: RH Forward Skirt

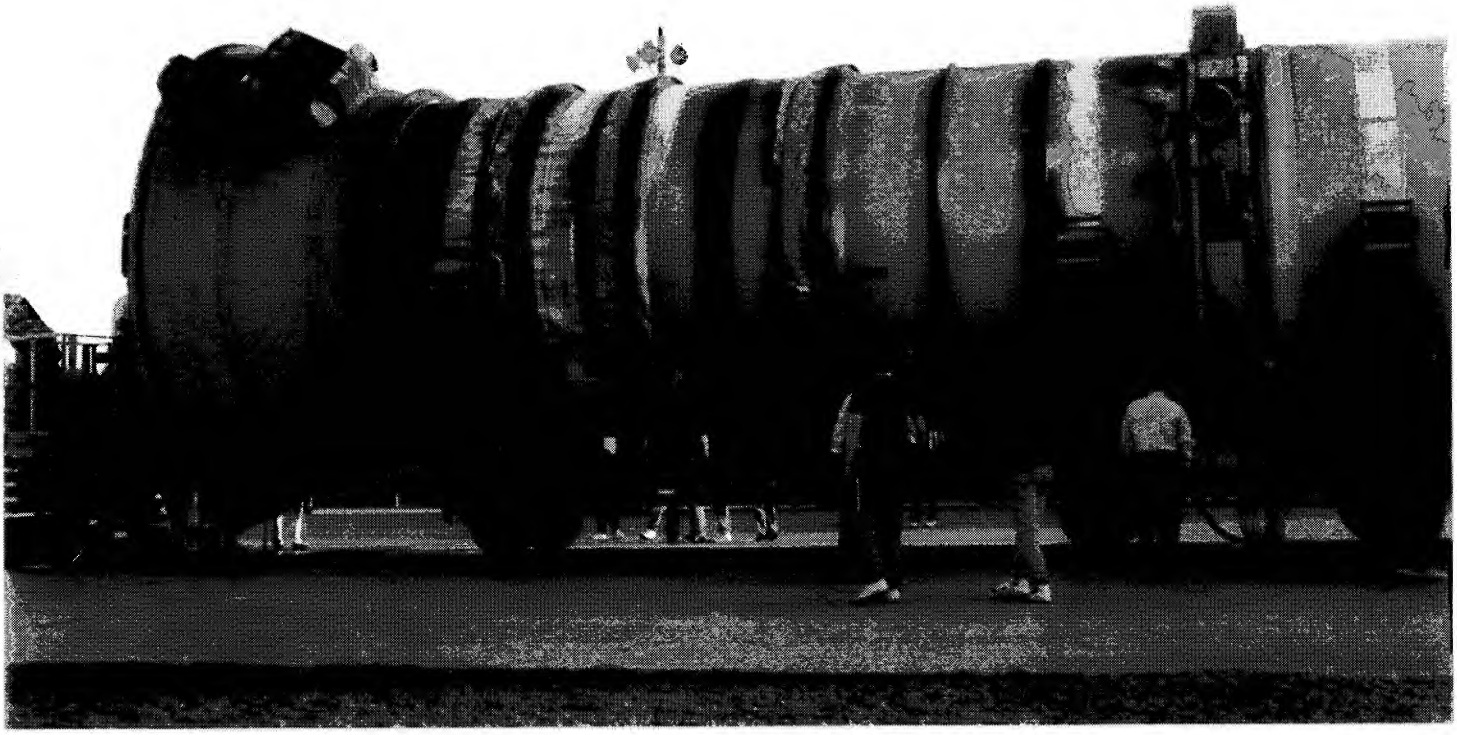


Photo 14: LH Aft Booster

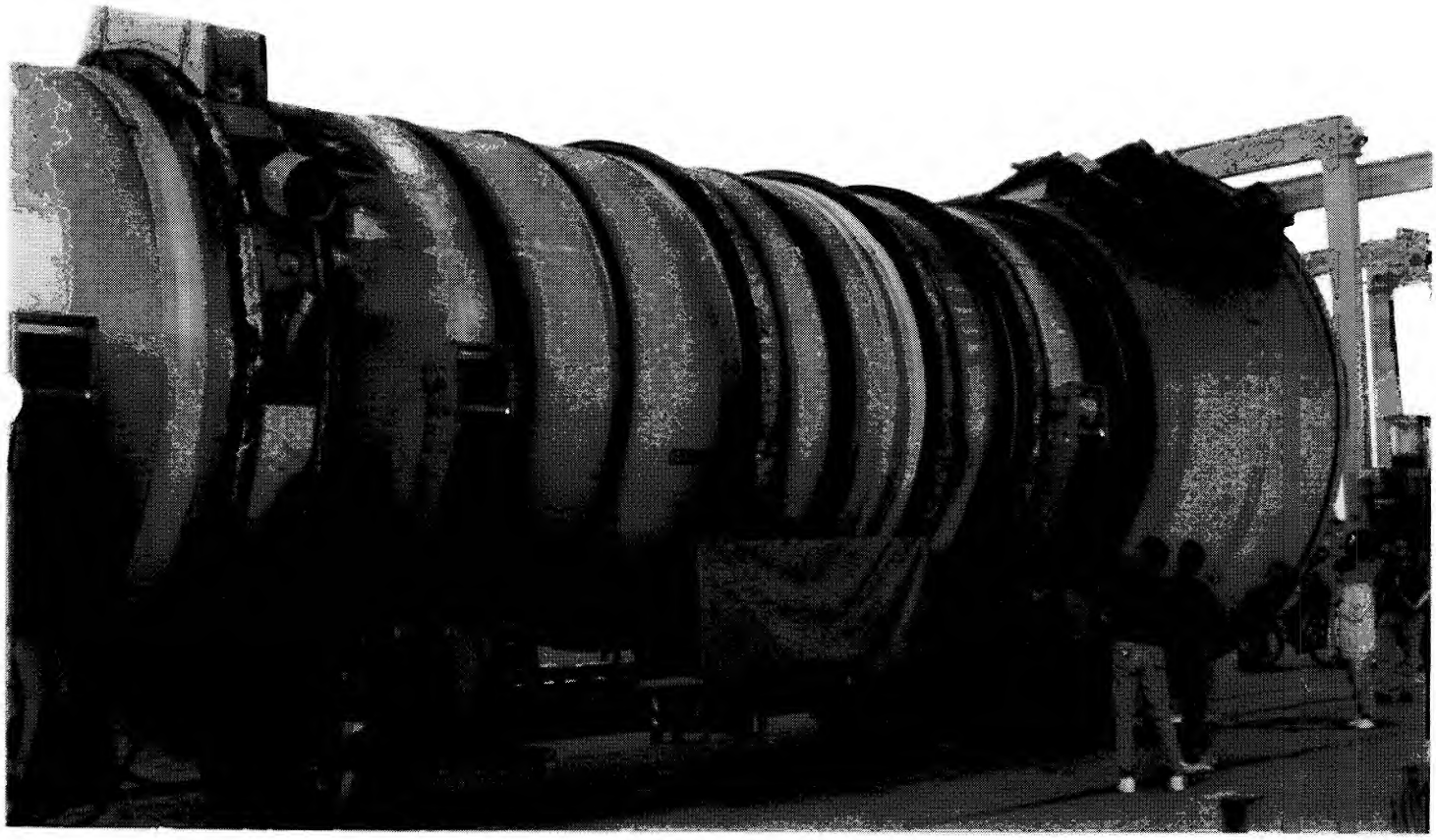


Photo 15: RH Aft Booster

Photo 16: Obstructed Debris Containment System

HDP#4 Debris Containment System was obstructed by a frangible nut half. This condition may have been the result of splashdown.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing inspection of OV-103 Discovery was conducted 21-23 February 1997 at the Kennedy Space Center on SLF runway 15 and in the Orbiter Processing Facility bay #2. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 103 hits, of which 18 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 66 previous missions of similar configuration (excluding missions STS-23, 24, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger were less than average (reference Figures 1-5).

The following table breaks down the STS-82 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	14	53
Upper surface	4	39
Right side	0	3
Left side	0	3
Right OMS Pod	0	2
Left OMS Pod	0	3
TOTALS	18	103

The Orbiter lower surface tiles sustained 53 damage sites, of which 14 were larger than 1-inch long in size. The largest lower surface tile damage site was located on the left chine about midway between the nose gear door and the left main gear door. The site measured 2-inches long by ¼-inch wide by 1/16-inch maximum depth.

Tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals were typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the air stream, both of which were observed in launch films.

No tile damage from micrometeorites or on-orbit debris was identified during this inspection.

The tires and brakes were reported to be in good condition for a landing on the KSC concrete runway. There was no ply undercutting visible on any of the tires.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities with the exception of a 2-inch long piece of white RTV. Loose pieces of white RTV hung from several umbilical pyro separation devices. Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect.

Bent metal, approximately 1-inch in length by 1/4-inch wide, was visible on the trailing edge of a spacer between two bolt heads on the inside surface of the LO2 ET door near the forward outboard corner.

The SSME #2 and #3 Dome Mounted Heat Shield (DMHS) closeout blankets were in excellent condition. SSME #1 blankets were slightly frayed at the 5:00 o'clock position.

Damage to base heat shield tiles, attributed to SSME vibration/acoustics and exhaust plume recirculation, appeared somewhat more than usual. Two adjacent tiles close to SSME #1/#3 base mounted heat shields exhibited a cluster of seven large damage sites. A similar cluster of six damage sites spanning four tiles occurred in a mirror-image area outboard of the SSME #1/#2 base mounted heat shields. These two locations may be vibration/acoustic focal points. A base mounted heat shield tile at the SSME #2 4:00-5:00 o'clock position was missing a 4-inch by 2-inch by 1-inch deep corner piece. The opposite corner of this same tile sustained a 3-inch crack.

Tiles on the upper surface of the body flap near the outboard edges sustained greater than usual damage from downward firing RCS thrusters.

Tiles on the vertical stabilizer "stinger" were intact and mostly undamaged. One small damage site was attributed to a launch debris impact rather than contact from drag chute risers.

No ice adhered to the payload bay door. No unusual tile damage was observed on the leading edge of the vertical stabilizer. Likewise, no significant tile damage occurred on the OMS pods, though a total of six gap fillers protruded from leading edge tiles.

Hazing and streaking of forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be average in size and number. A somewhat unusual finding consisted of a cluster of 14 hits, including four larger than 1-inch, in the black-tiled area between windows #3 and #4. These damage sites are believed to be the result of impacts from FRCS thruster paper covers/RTV adhesive.

The post landing walkdown of Runway 15 was performed immediately after landing. No debris concerns were identified. All drag chute hardware was recovered and appeared to have functioned normally.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were less than average when compared to previous missions.

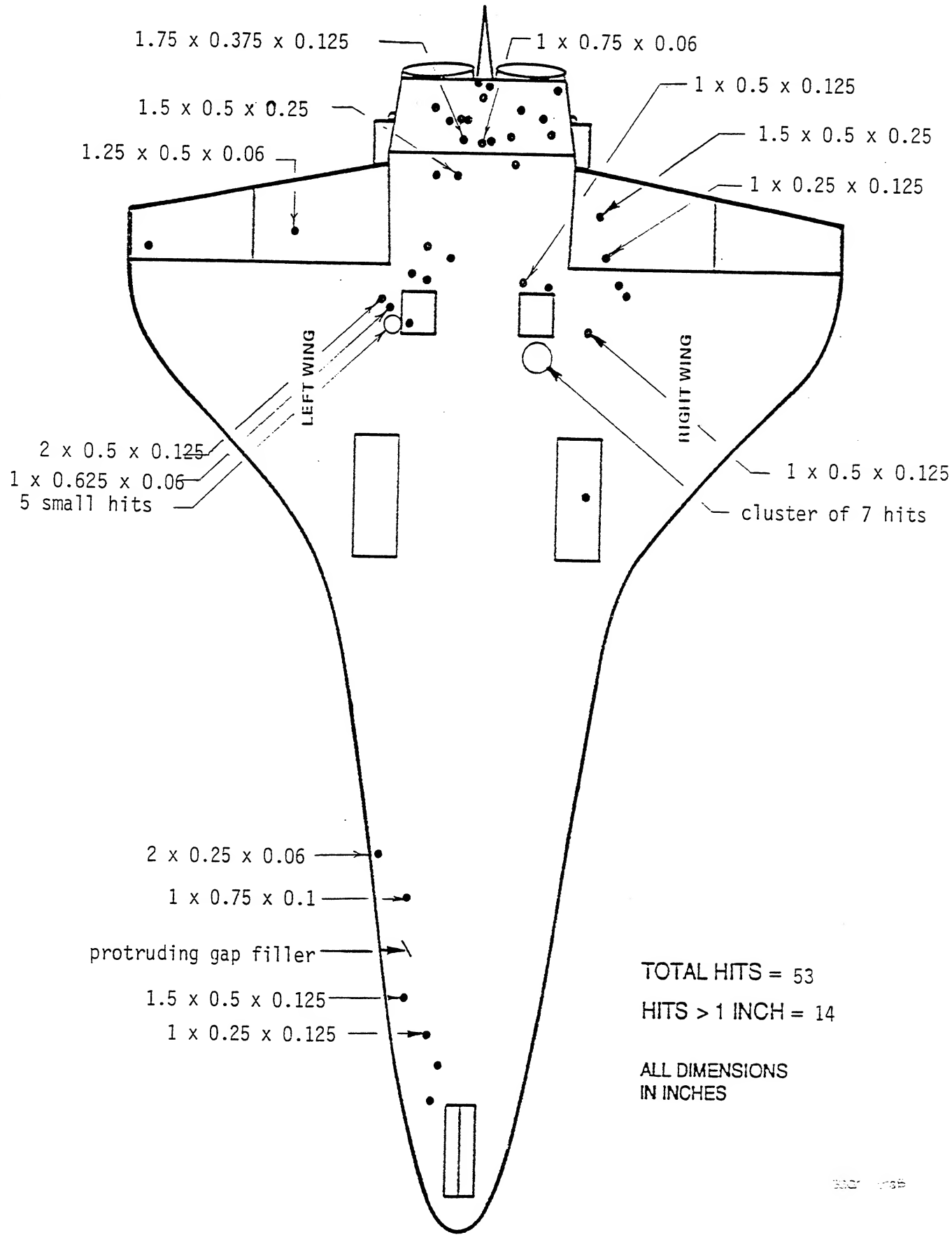


Figure 1: Orbiter Lower Surface Debris Damage Map

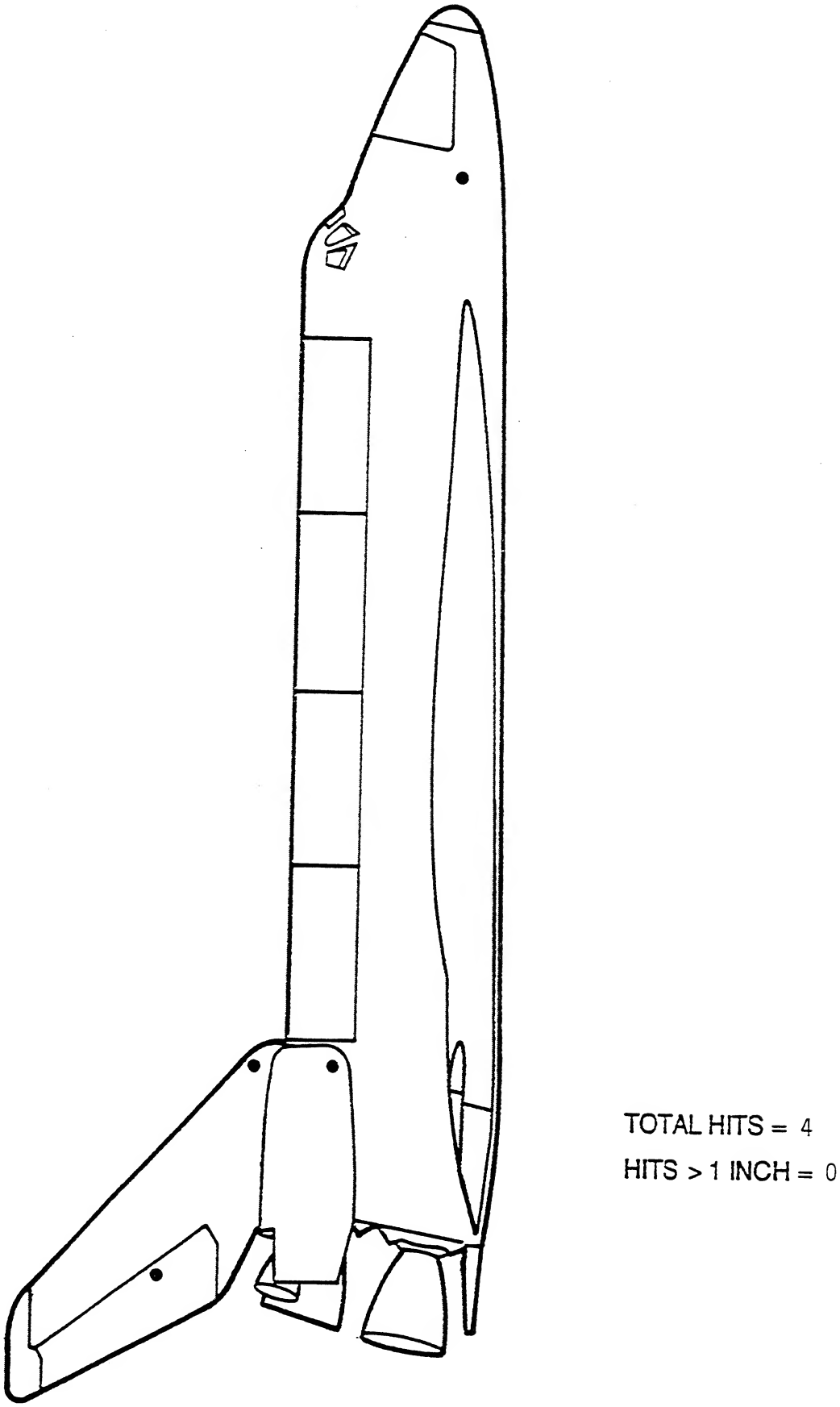


Figure 2: Orbiter Right Side Debris Damage Map

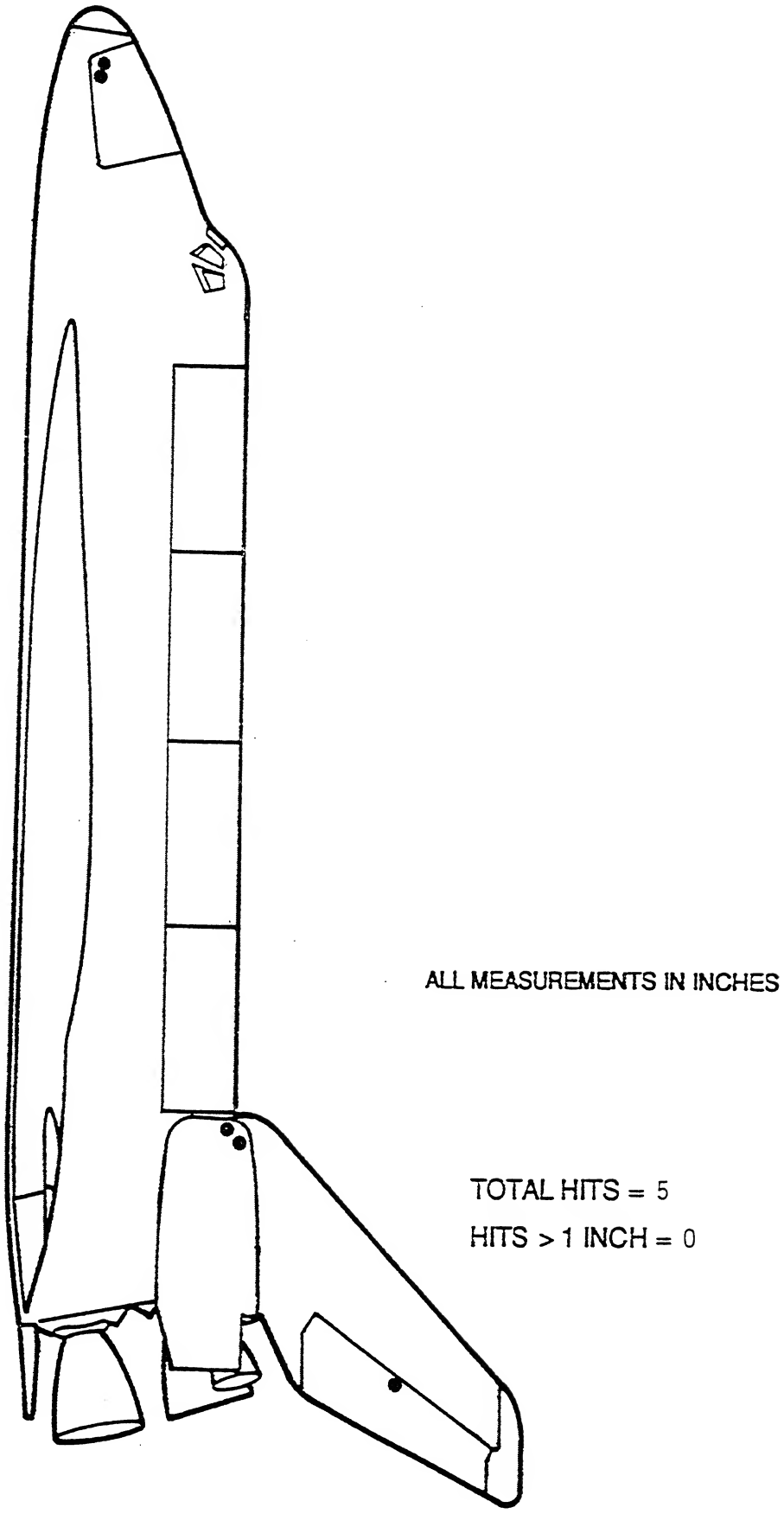


Figure 3: Orbiter Left Side Debris Damage Map

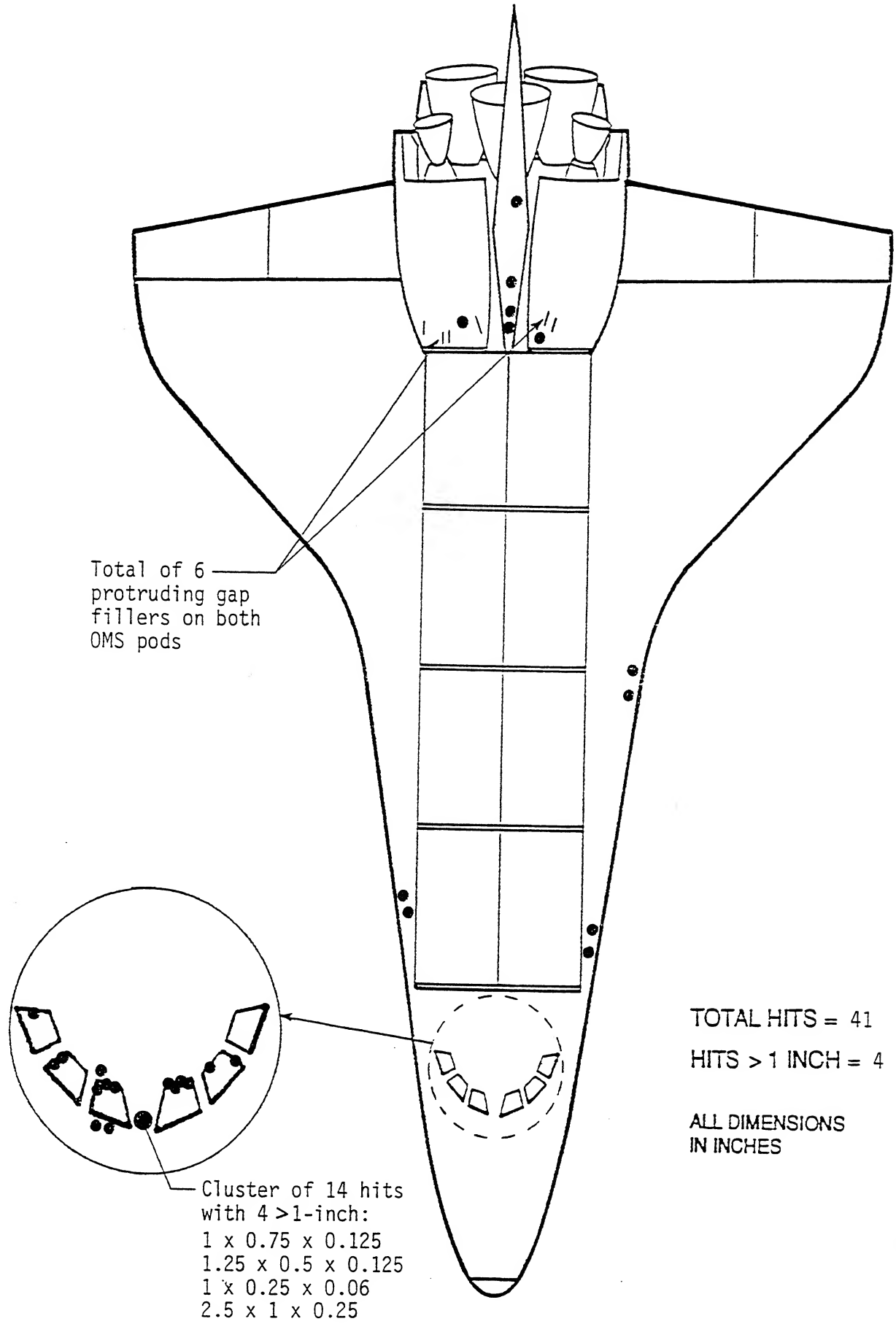


Figure 4: Orbiter Upper Surface Debris Damage Map

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	21	89	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
STS-75	11	55	17	96
STS-76	5	32	15	69
STS-77	15	48	17	81
STS-78	5	35	12	85
STS-79	8	65	11	103
STS-80	4	34	8	93
STS-81	14	48	15	100
AVERAGE	13.5	86.1	20.0	126.4
SIGMA	7.3	44.1	9.7	53.2
STS-82	14	53	18	103

MISSIONS STS-23,24,25,26,26R,27R,30R,AND42R ARE NOT INCLUDED IN THIS ANALYSIS
SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 5: Orbiter Post Flight Debris Damage Summary

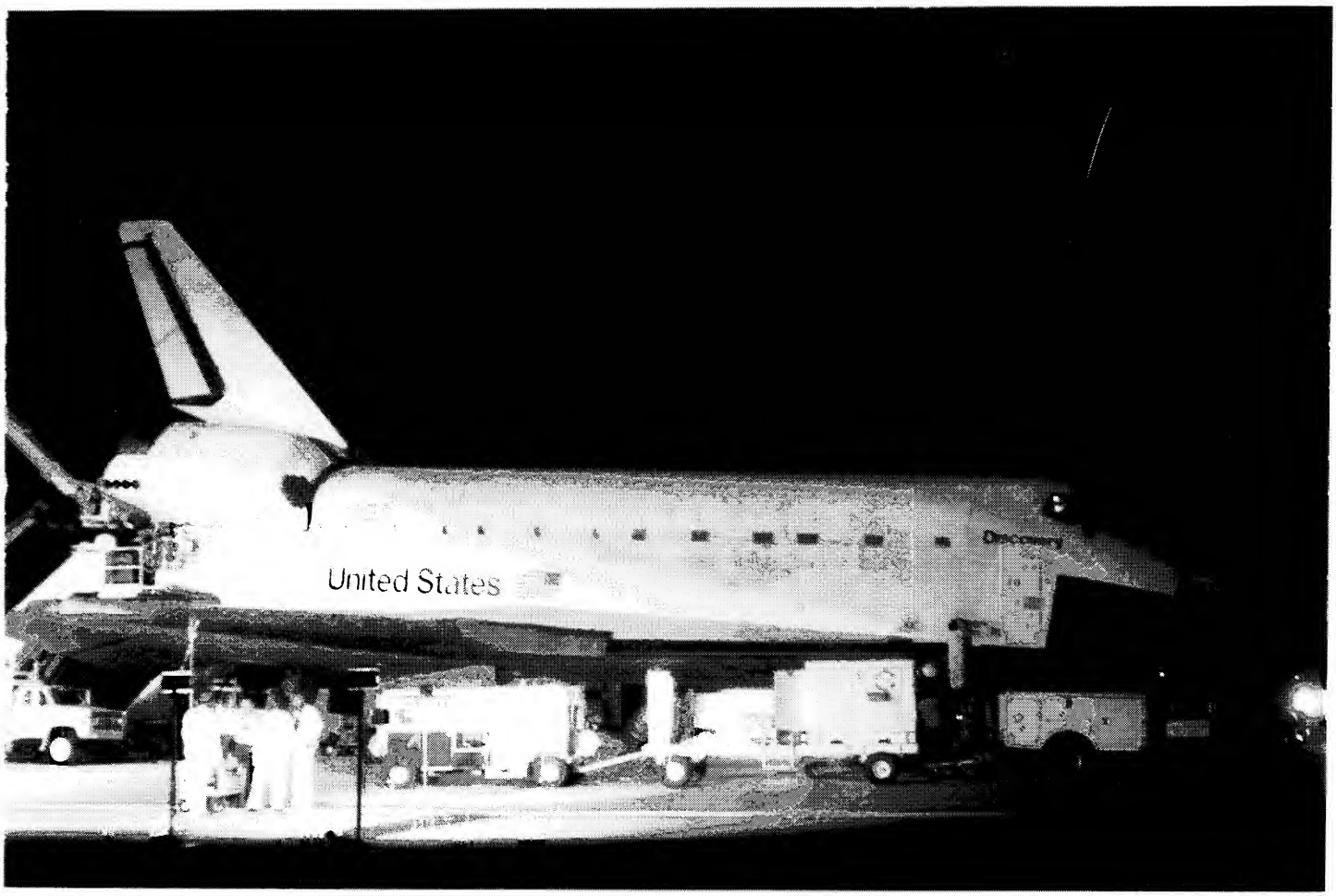


Photo 17: Overall View of Orbiter Right Side

Photo 18: Overall View of Orbiter Left Side

Photo 19: Body Flap Upper Surface Tile Damage

Tiles on the upper surface of the body flap near the outboard edges sustained greater than usual damage from downward firing RCS thrusters.

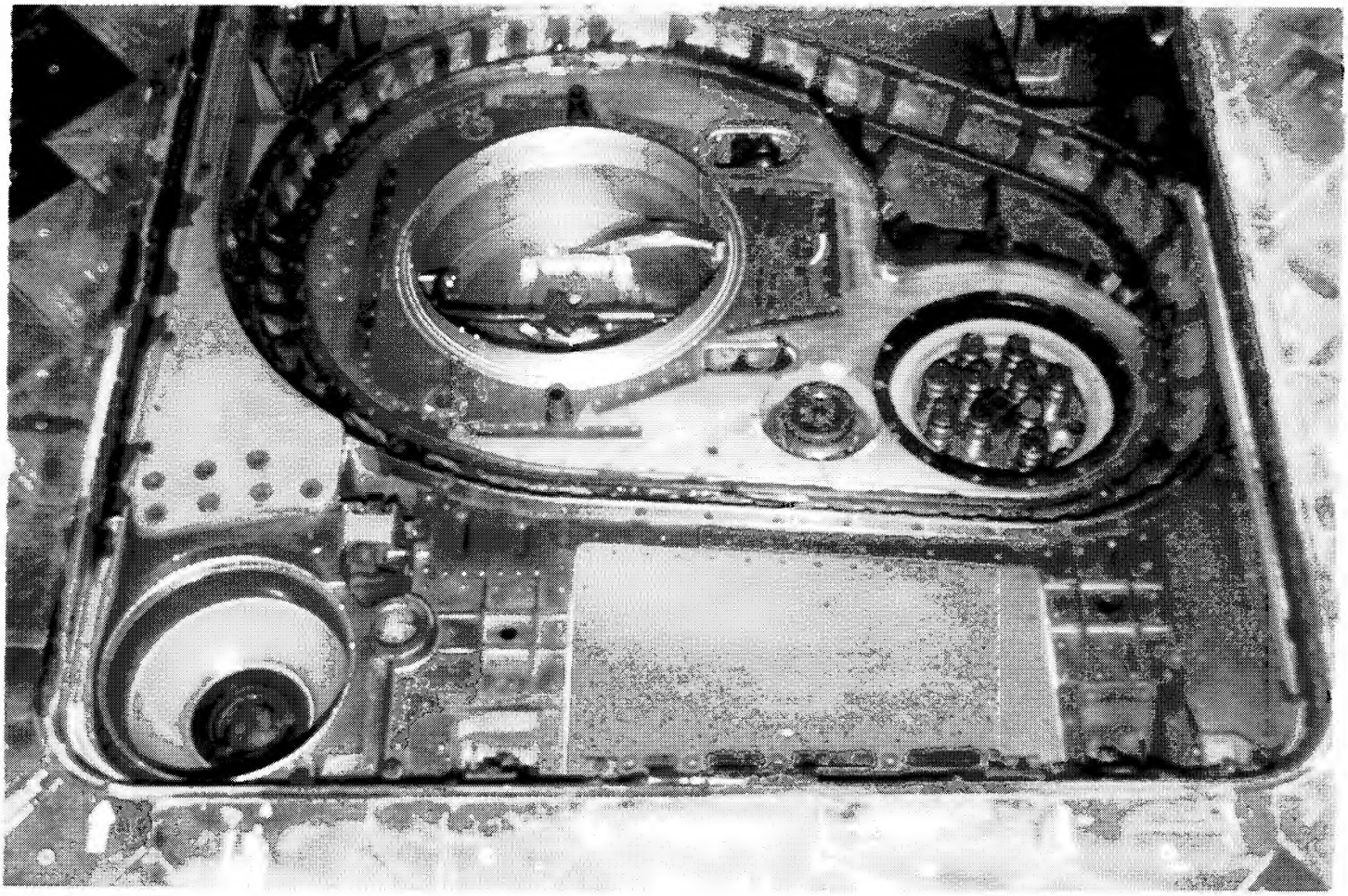


Photo 20: LO2 Umbilical

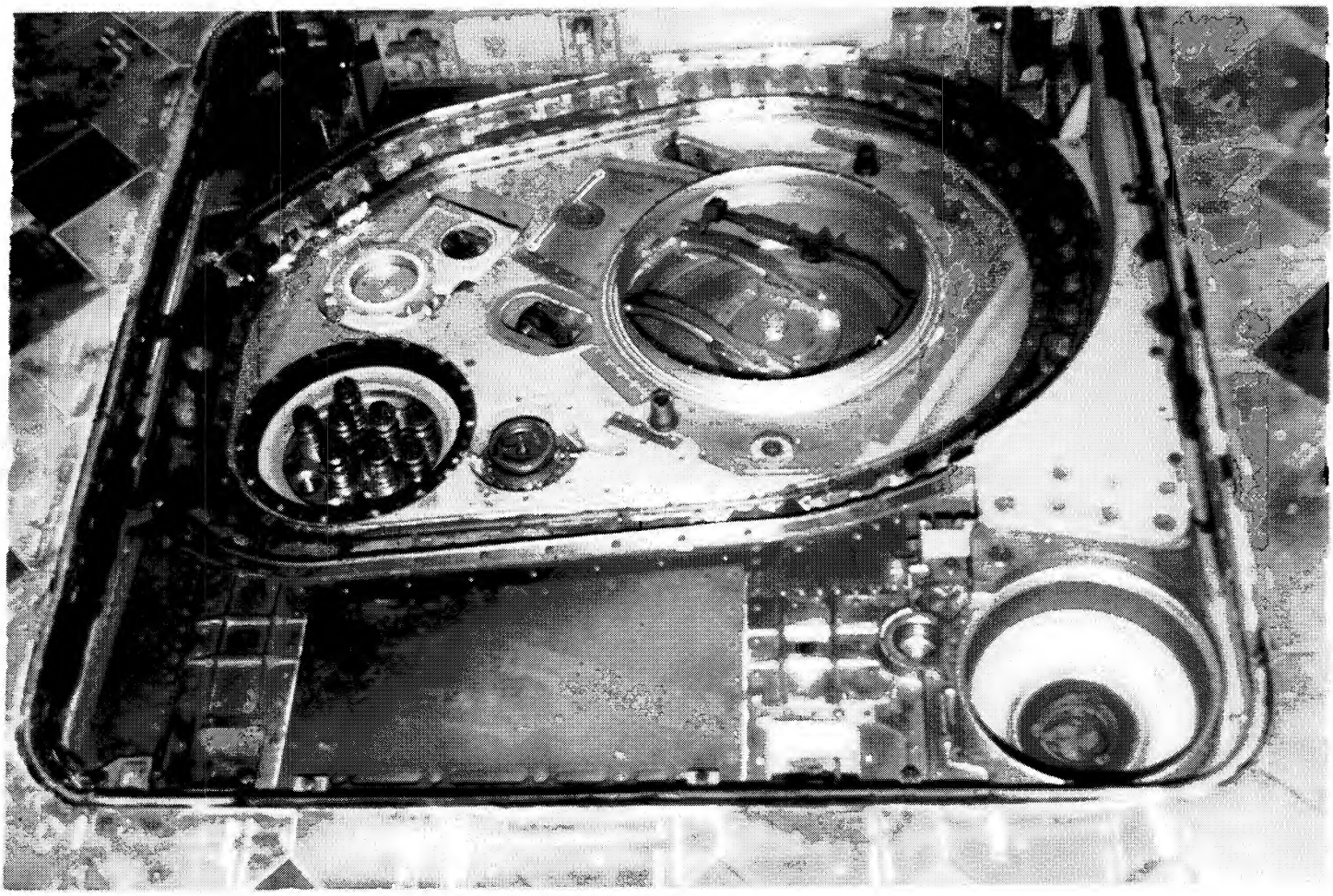


Photo 21: LH2 Umbilical

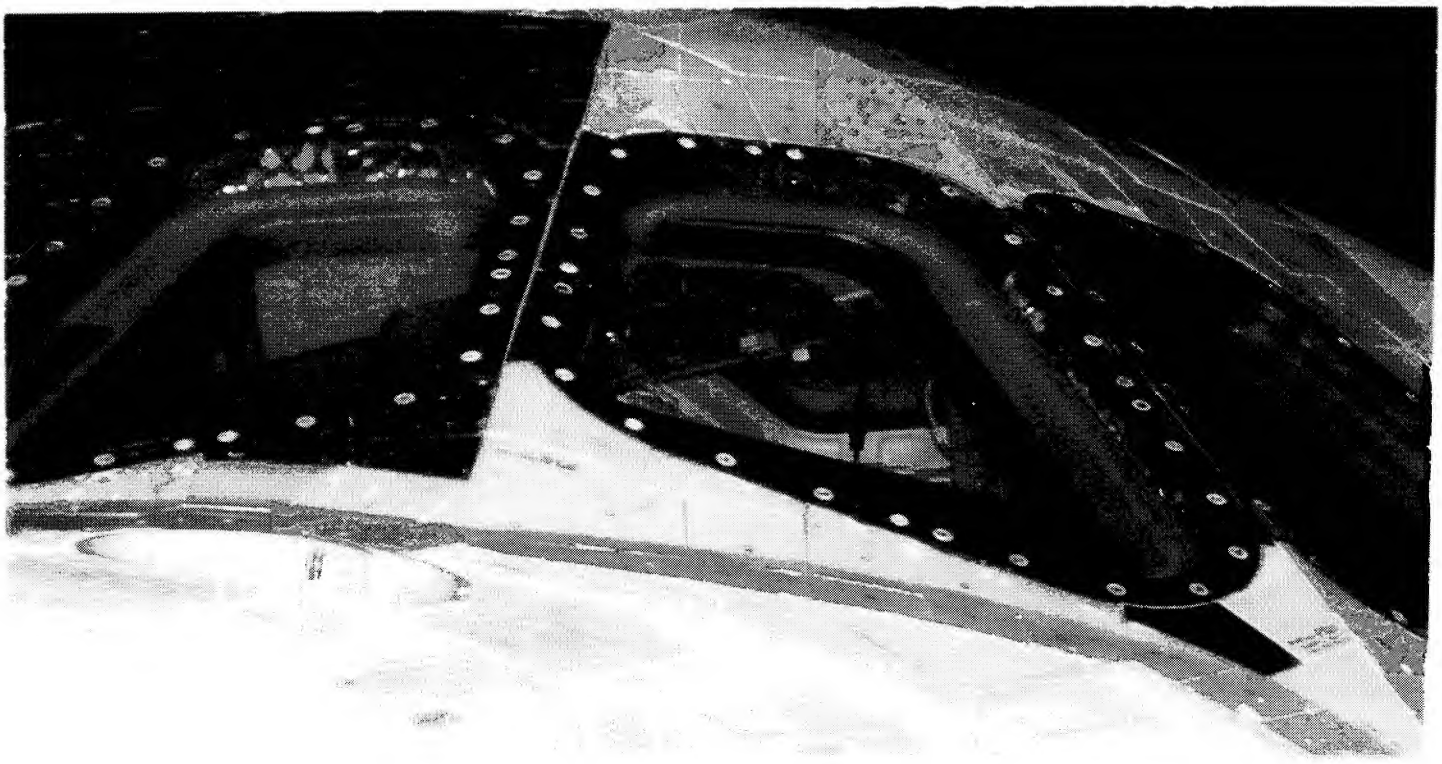


Photo 22: Orbiter Windows 1 - 3

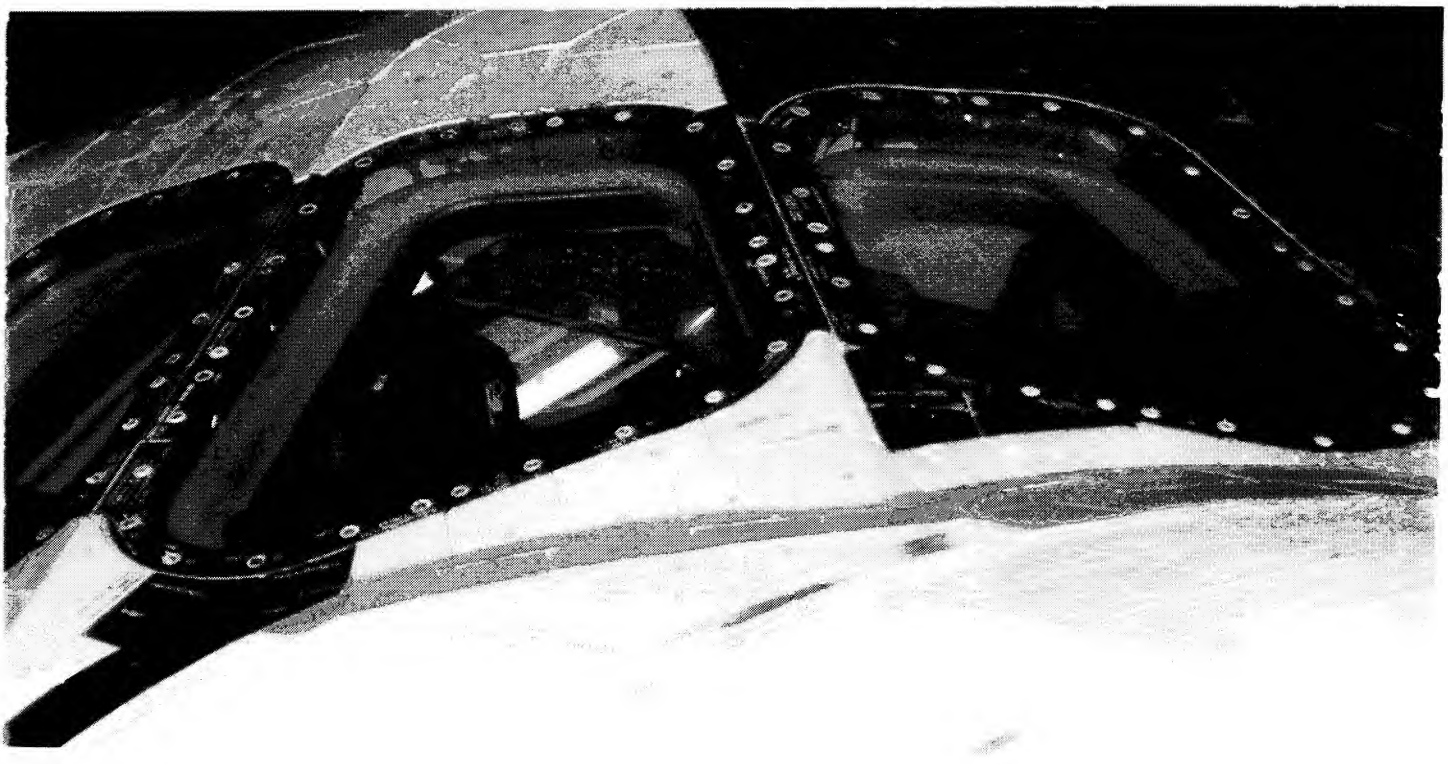


Photo 23: Orbiter Windows 4 - 6

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

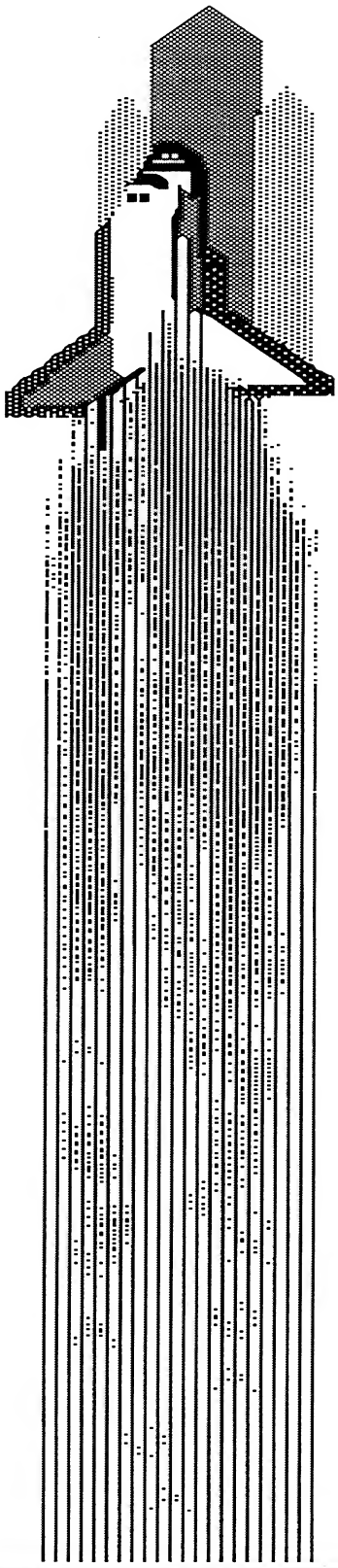
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-82 Summary of Significant Events

March 21, 1997



Space Shuttle Image Science and Analysis Group

STS-82 Summary of Significant Events

Project Work Order - SN-5LA

Approved By

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Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

Table of Contents

List of Tables and Figures

1. STS-82 (OV-103): FILM / VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-82 night-time launch of Discovery (OV-103) from pad A occurred on Tuesday, February 11, 1997, (day 042) 08:55:17.024 Coordinated Universal Time (UTC) as seen on camera E9. Solid Rocket Booster (SRB) separation occurred at 08:57:20.7 UTC as seen on camera KTV13.

On launch day, 24 of the 24 expected videos were received and screened. Following launch day, twenty-one films were screened. Twenty-two additional films were received for contingency support and anomaly resolution, but were not screened since there were no major launch/ascent issues. No anomalies that could threaten vehicle safety were seen on the launch imagery. Camera film E76 was not received.

Detailed Test Objective 312 was performed using handheld photography. The photography of the ET was acquired using the Nikon F4 camera with the 400 mm lens and 2x converter (method 4). Umbilical well films were not acquired (method 1) because OV-103 is not configured to fly these cameras.

1.1.2 On-Orbit

No unplanned on-orbit analysis support was requested. Pre-planned real-time analysis support was provided to the Hubble Space Telescope capture, repair, and deploy. Measurements made on Solar Array twist and motion were provided to GSFC after each EVA. Results of this analysis will be published separately.

1.1.3 Landing

Discovery landed at night on runway 15 at the KSC Shuttle Landing Facility on February 21, 1997. Ten videos were received and screened. Following landing, seven films were screened.

No major anomalies were noted in the approach, landing, or roll-out video and film views screened. The drag chute deployment appeared normal.

Normal APU venting was seen during the landing approach through roll-out and wheel stop (Cameras EL17IR, EL18IR). Also, contrails were seen trailing from the Orbiter wing tips prior to landing (Cameras KTV6L, KTV11L, KTV15L, KTV20L, KTV33L, EL17IR, and SLF South). The Orbiter was seen to track to the right of the runway centerline after touchdown (Cameras SLF North and SLF South).

1.1.4 Post Landing

The following items were seen during the post landing walk-around: erosion/chipping of the surface area of several tiles on the base heat shield, tile damage on the upper surface of the body flap, and a loose strip of white material (reported to be RTV) in the LH2 umbilical.

1.2 TIMING ACTIVITIES

The time codes from videos and films were used to identify specific events during the initial screening process.

The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing Gear - Doors Opened	052:08:32:04.867	KTV20L
Right Main Wheel Touchdown	052:08:32:23.833	EL17IR
Left Main Wheel Touchdown	052:08:32:23.867	EL17IR
Drag Chute Initiation	052:08:32:27.200	SLF N
Pilot Chute at Full Inflation	052:08:32:28.067	SLF N
Bag Release	052:08:32:28.700	KTV15L
Drag Chute Inflation in Reefed Configuration	052:08:32:29.633	KTV33L
Drag Chute Inflation in Dis-reefed Configuration	052:08:32:32.967	KTV33L
Nose Wheel Touchdown	052:08:32:34.733	EL17IR
Drag Chute Release	052:08:32:55.733	KTV33L
Wheel Stop	052:08:33:16.333	KTV33L

Table 1.2 Landing Video Event Timing

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS DURING SSME IGNITION THROUGH LIFTOFF

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition through liftoff. No damage to the vehicle was noted. No follow-up action was requested.

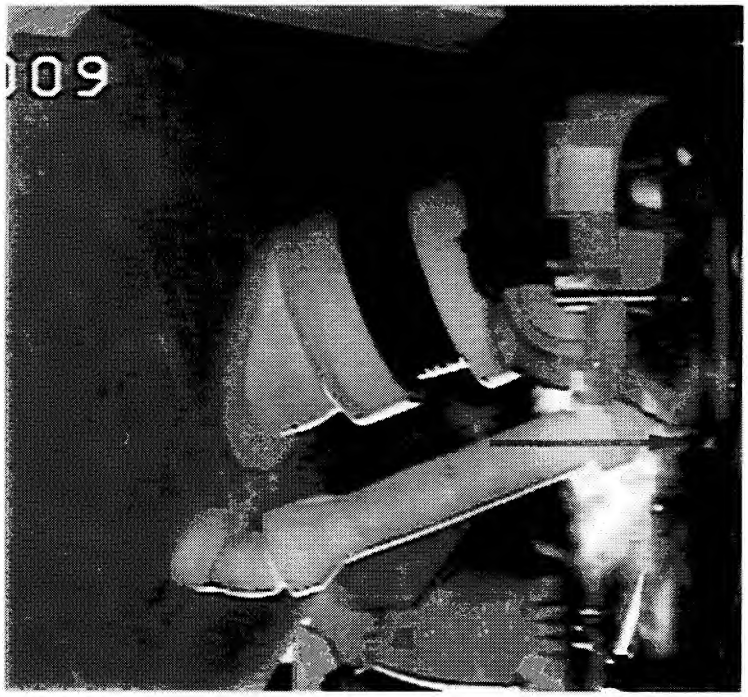

Figure 2.1 (A) Ice Debris Strike to Umbilical Well Door Sill

Multiple pieces of ice debris were seen falling from the LH2 ET/Orbiter umbilical during SSME ignition. Ice debris was seen to strike the LH2 umbilical well door sill (08:55:11.86 UTC) and the LH2 four inch recirculation line (08:55:15.20 UTC). No damage was noted (Camera OTV009).

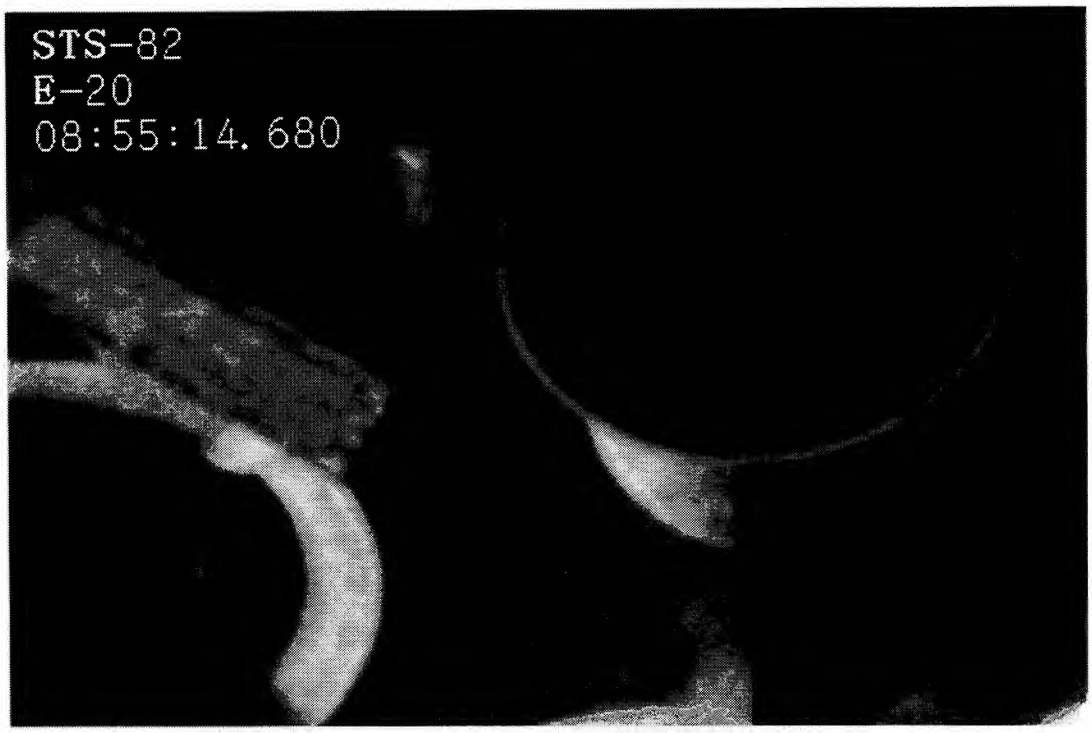

Figure 2.1 (B) Possible Tile Shim Debris Near Left RCS Stinger

A single, red-colored, rectangular-shaped piece of debris (possibly a tile shim) was seen coming from behind the left RCS stinger and fell aft between SSME #1 and SSME #2 during SSME ignition (08:55:14.680 UTC). No follow-up action was requested (Camera E20).

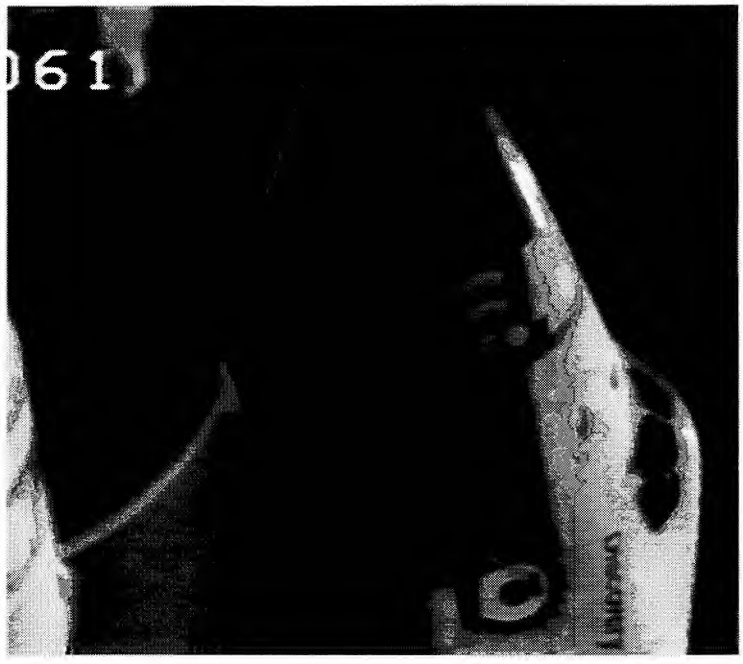

Figure 2.1 (C) White Debris Near ET Upper Feedline Bellows

Four pieces of white debris, first seen near the ET upper feedline bellows, fell aft between the Orbiter and the ET just prior to liftoff (08:55:14.0 UTC). A fifth

piece of debris, also from near the LO2 upper feedline bellows, fell aft at liftoff (08:55:17.6 UTC) (camera OTV061). On camera E34, a single light-colored piece of debris was seen falling between the ET and the Orbiter (forward of the ET/Orbiter umbilicals) at liftoff (08:55:19.822 UTC). These debris were not seen to contact the vehicle.

Several pieces of light-colored debris were seen falling aft along the right inboard elevon at liftoff (08:55:18.050 UTC) on camera E5. A small light-colored, rectangular-shaped piece of unidentified debris was seen falling along the LO2 TSM (08:55:18.315 UTC) on camera E17. These debris were not seen to contact the vehicle.

A dark tape-like piece of debris, first seen near the LSRB, fell aft of the launch vehicle into the exhaust cloud during liftoff (08:55:19.028 UTC) (Camera E4).

A single piece of SRB flame duct debris was seen north of the launch vehicle during liftoff (08.55.19.144 UTC). The debris was not seen to contact the vehicle (Camera E52, OTV070, KTV7A).

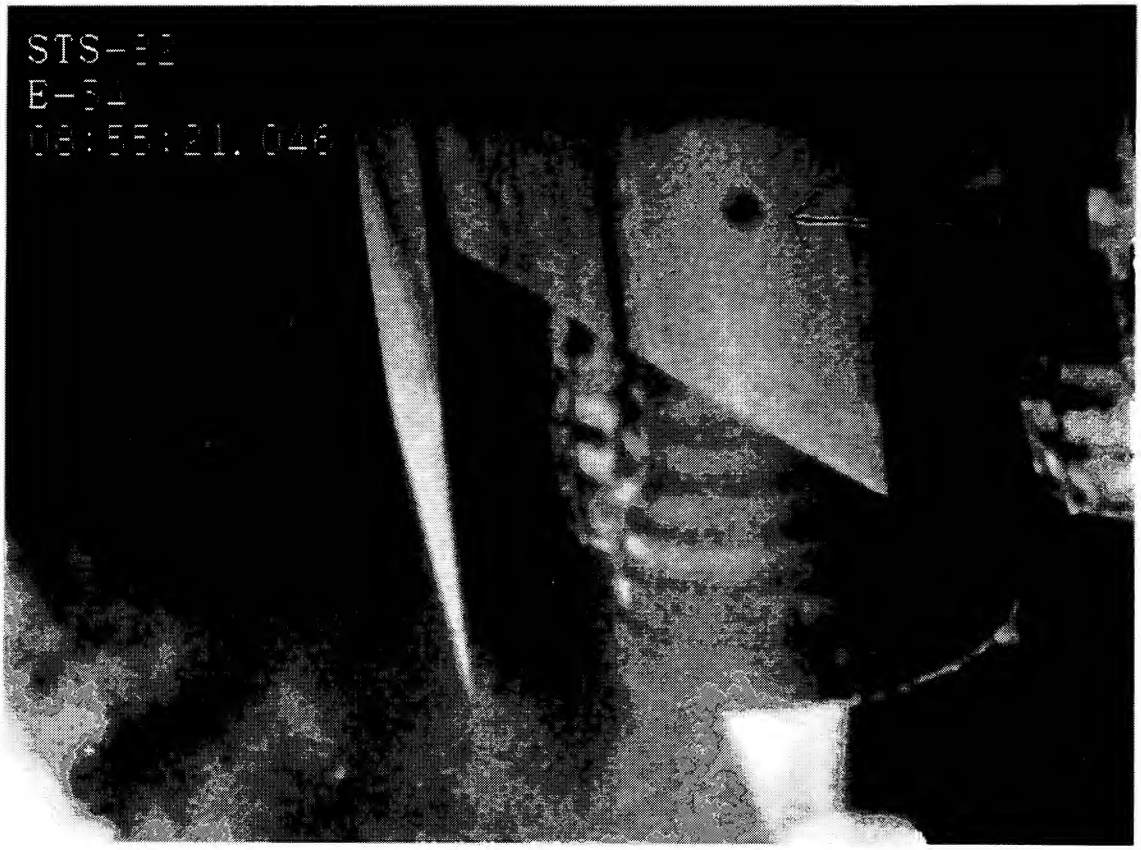

Figure 2.1 (D) Unidentified Piece of Debris Near Left Elevon

A dark unidentified piece of debris (possibly a bird) was seen falling aft near the left elevon during liftoff (08:55:21.046 UTC) (Camera E34).

2.2 DEBRIS DURING ASCENT

During ascent, multiple pieces of debris (probably umbilical ice and RCS paper) fell aft of the launch vehicle. No damage to the vehicle was noted. No follow-up action was requested. (Cameras E52, E54, E207, E212, E220, E222).

Figure 2.2 (A) Debris at Beginning of Roll Maneuver.

Debris (probably ET/Orbiter purge barrier material) fell aft of the launch vehicle at the beginning of the roll maneuver (08:55:27.0 UTC). A long piece of tape-like material (probably from the ET/Orbiter umbilical area) was also seen falling aft along the body flap (08:55:27.6 UTC) (Cameras E52, E54, E212, E222, E223).

Debris (probably umbilical ice) was seen aft of the Shuttle Launch Vehicle during the roll maneuver (08:55:27, 08:55:30, 08:55:31, and 08:55:33 UTC) (Cameras E52, E54). Debris first seen near the base of the vertical stabilizer at 08:55:38.6 UTC were probably RCS paper (Cameras E220, E222, E223).

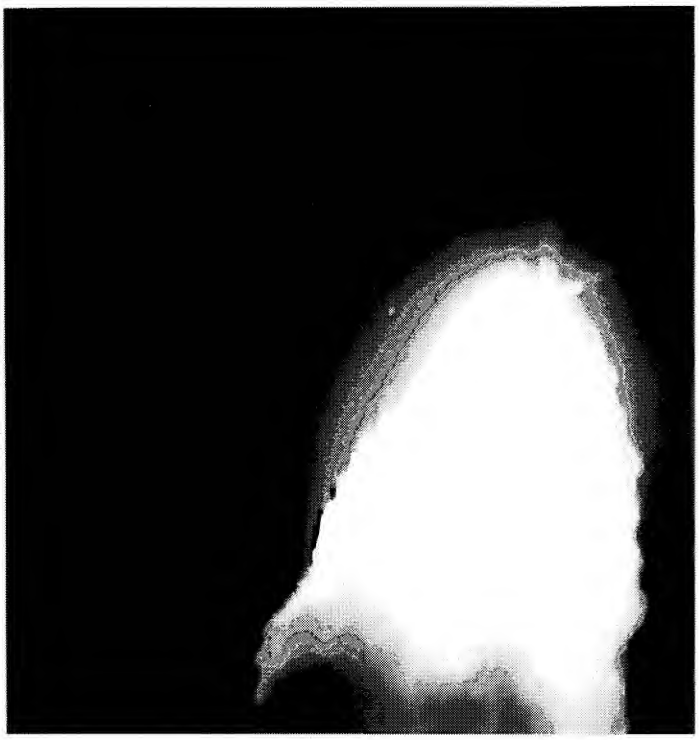

Figure 2.2 (B) Debris Near SRB Exhaust Plume During Ascent

Multiple pieces of debris (possibly instafoam from the SRB aft skirts) were seen falling along the SRB exhaust plume after the roll maneuver between 08:55:38 and 08:55:53 UTC (Cameras E220, E222, E223, E224), and between 08:56:24 and 08:56:36 UTC (Cameras KTV4A and KTV13). Three pieces of debris were also seen falling along the SRB exhaust plume between 08:57:17 and 08:57:19 UTC (Cameras KTV4A and KTV13).

Three pieces of debris, first seen near the RSRB, fell aft in the SSME exhaust plume during ascent (08:55:35.6 - 08:55:38 UTC). Two of the debris pieces appeared to travel toward SSME #1 before falling aft (Camera E212, E220, E223).

2.3 MOBILE LAUNCH PLATFORM (MLP) EVENTS

The SSME Mach diamond formation appeared to occur out of sequence. No follow-up action was requested. The times of the Mach diamond formation were (Camera E19):

SSME #2 -08:55:13.839 UTC
SSME #3 -08:55:13.955 UTC
SSME #1 -08:55:14.155 UTC

Figure 2.3 Orange Vapor during SSME Ignition

Orange vapor, probably free burning hydrogen, was seen above the SSME rims, near the body flap, and near the base of the vertical stabilizer during SSME ignition (08:55:14 UTC). Orange vapors have been seen on previous missions (Cameras OTV071, E4, E19).

2.4 ASCENT EVENTS

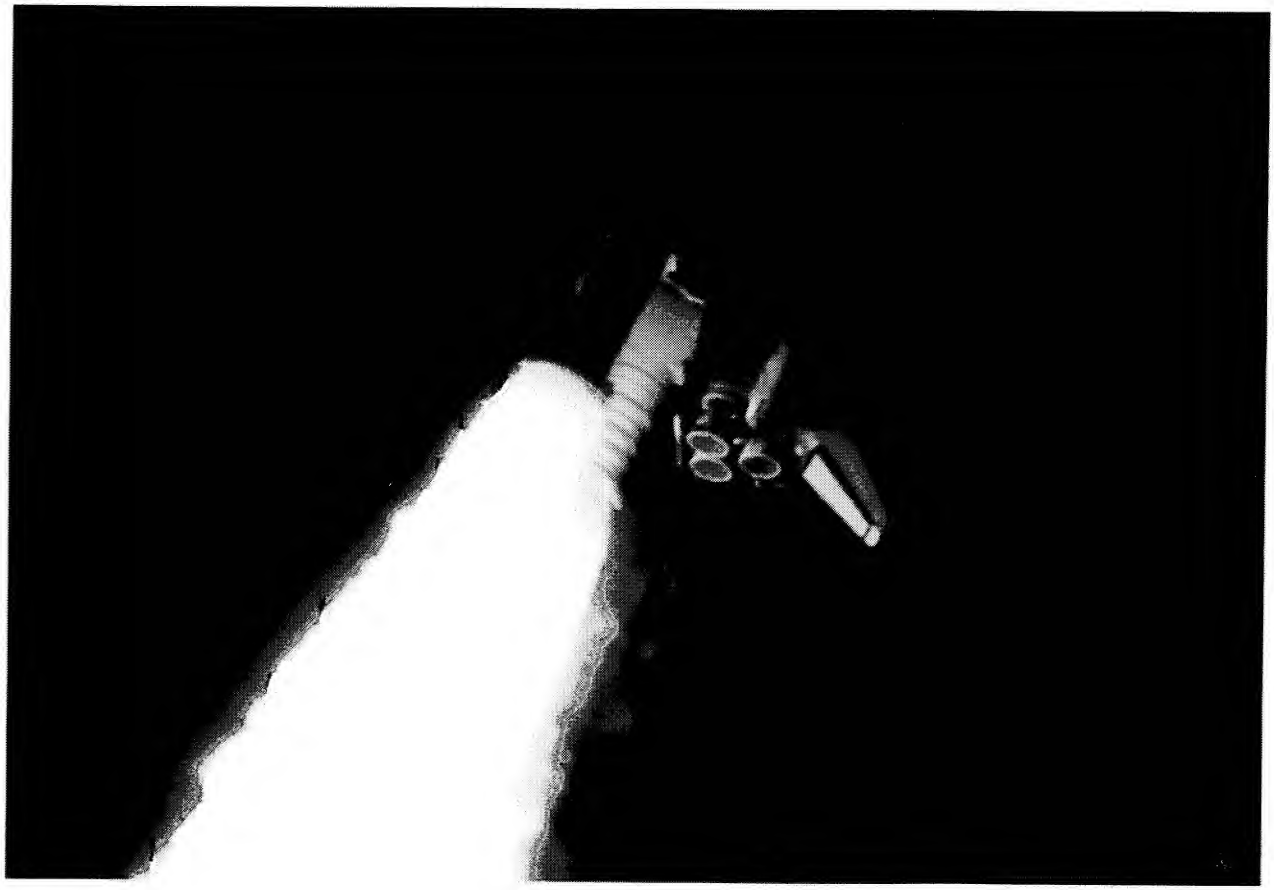

Figure 2.4 (A) Flare in SSME Exhaust Plume

Seven orange-colored flares (probably RCS paper debris induced) were seen in the SSME exhaust plume during ascent (Cameras E220, E212, E222, E223). The orange-colored flares were seen over a five second time period beginning at 08:55:50.695 UTC (33.671 seconds MET). Flares in the SSME exhaust plumes have been seen on previous missions. However, the rapid succession of the STS-82 flares and the resultant color changes seen in the SSME exhaust plumes were more obvious than typically seen on previous missions. Camera film (E220) of the flares was reviewed with an engineer from the JSC Structures and Mechanics Divison/ES3. The ES3 engineer concluded that the flares were not caused by falling tiles. No follow-up action was requested. A description of the flare events is shown in Table 2.4.

TIME (UTC)	EVENT
42:08:55:49.540	Two Pieces of Debris Near Vertical Stabilizer.
42:08:55:50.670	Debris Near Vertical Stabilizer.
42:08:55:50.695	**Orange Flare in SSME #2/3 Exhaust Plume.**
42:08:55:50.705	Orange Flare Disappears. Red Hue Remains .
42:08:55:50.750	Exhaust Plume of SSME #2/3 Appears Normal.
42:08:55:50.770	Debris Near Vertical Stabilizer Tip.
42:08:55:50.890	**Orange Flare from SSME #3 Rim.**
42:08:55:50.900	Orange Flare from SSME #3 Rim Disappears.
42:08:55:51.290	**Orange Flare from SSME #3 Rim.**
42:08:55:51.310	Orange Flare from SSME #3 Rim Disappears.
42:08:55:51.915	**Orange Flare in SSME #1 Exhaust.**
42:08:55:51.925	Orange Flare in SSME #1 Exhaust Disappears.
42:08:55:55.173	**Red Color in All Three SSME Exhaust Plumes.**
42:08:55:55.205	Orange Color in SSME #3 Exhaust Disappears.
42:08:55:55.640	**Orange Flare from SSME #3 Rim Deflects Off Exhaust.**
42:08:55:55.660	**Orange Color in SSME #2/3 Exhaust Plume.**
42:08:55:55.665	**Orange Flare from SSME #3 Rim (Opposite Side).**
42:08:55:55.665	**Orange Color Throughout Exhaust Plumes Continues.**
42:08:55:55.710	Both Flares from SSME #3 Rim Disappear.
42:08:55:55.735	**Sudden Yellow Glow Further Aft in SSME #2/3 Exhaust.**
42:08:55:55.770	**Orange Flare from SSME #3 Rim (Opposite Side).**
42:08:55:55.780	Orange Flare from SSME #3 Rim Disappears.
42:08:55:57.480	Single Piece of Debris Near RSRB.

Table 2.4 Flare Events from Camera E220.

Figure 2.4 (B) Recirculation at Aft End of Vehicle

Recirculation, or the expansion of burning gasses at the aft end of the vehicle, was seen during ascent (08:56:47 - 08:57:03 UTC). Recirculation during this time period has been seen on previous missions. (Cameras KTV13, ET204).

2.5 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.5.1 Analysis of Handheld Photography of the ET (Task #3)

Figure 2.5.1 (A) Handheld Camera View of the External Tank

DTO-312 (method 4) handheld photography of the STS-81 external tank after separation was acquired with a Nikon 35 mm camera with a 400 mm lens and a 2X extender. The OMS-2 attitude pitch maneuver was performed early to assist the crew members in acquiring the ET visually.

Twenty-nine views of the external tank were acquired (roll 316). Four views of an irregular-shaped piece of debris (probably ice) were also acquired. All sides and the nose of the ET were imaged, although the view angle did not always provide a good picture. Timing data is present on the hand-held film. The first picture was taken on February 11, 1997 at 09:20:00 UTC (approximately 25 minutes after liftoff) and the last picture was taken at 09:32:16 UTC.

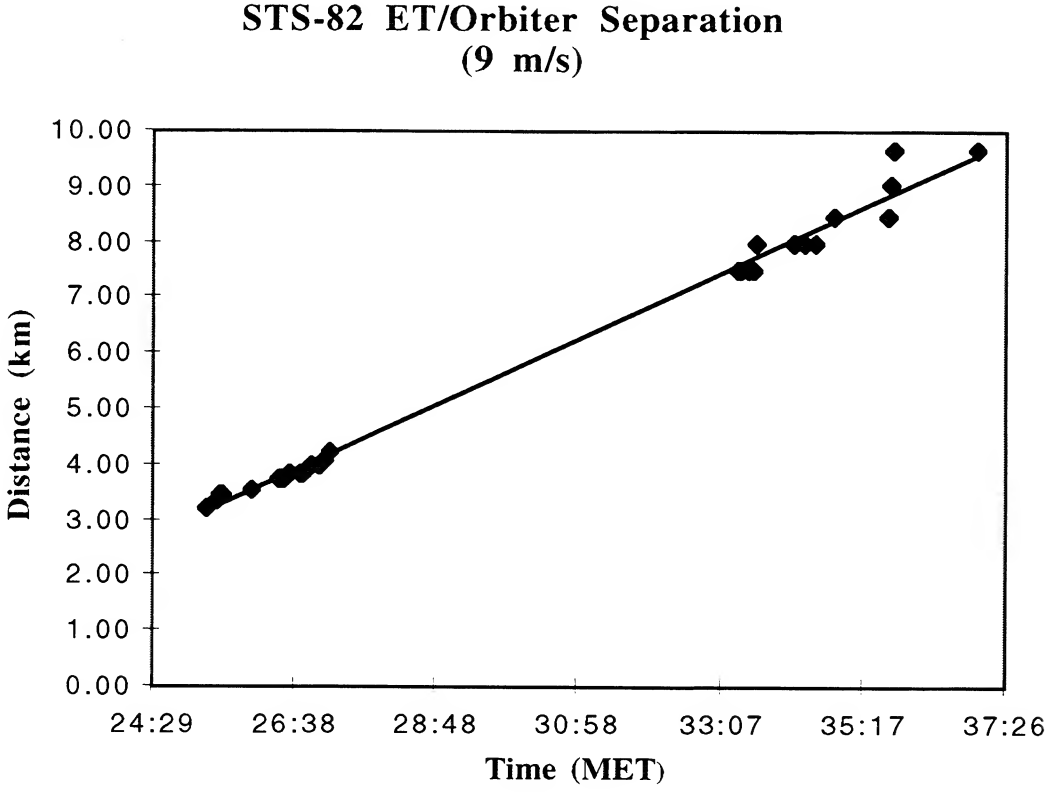

Figure 2.5.1 (B) ET Separation Velocity

The distance of the external tank was calculated on twenty-nine frames. On the first view, the external tank was calculated to be a distance of 3.2 km away from the Orbiter at 25:17 MET. On the last view, the tank was calculated to be at a distance of 9.7 km (11.3 minutes after the first view or 36.6 MET). The tank separation average velocity was determined to be 9 m/s with an uncertainty of approximately 1 m/s. The separation velocity was larger than previous mission measurements since the pictures were taken at a later time. The tank tumble rate was approximately 1.6 deg/sec and the roll rate was too small to be measured.

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis (Task #1)

Video camera SLF-South was used to determine the landing sink rate of the main gear and SLF-North was used to determine the nose gear sink rate (the film cameras did not provide adequate views due to darkness). The sink rates of the Orbiter were determined over a one-second time period prior to main and nose gear touchdown.

The measured main gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-82 Orbiter was reported to be 213,710 lb.). The sink rate measurements for STS-82 are given in Table 2.6.1. In Figure 2.6.1(A), and 2.6.1(B), the trend of the measured data points for the image data is illustrated.

Sink Rate Prior to Touchdown (1 Second)	
Main Gear	1.7 ft/sec
Nose Gear	2.8 ft/sec

Table 2.6.1 Sink Rate Measurements

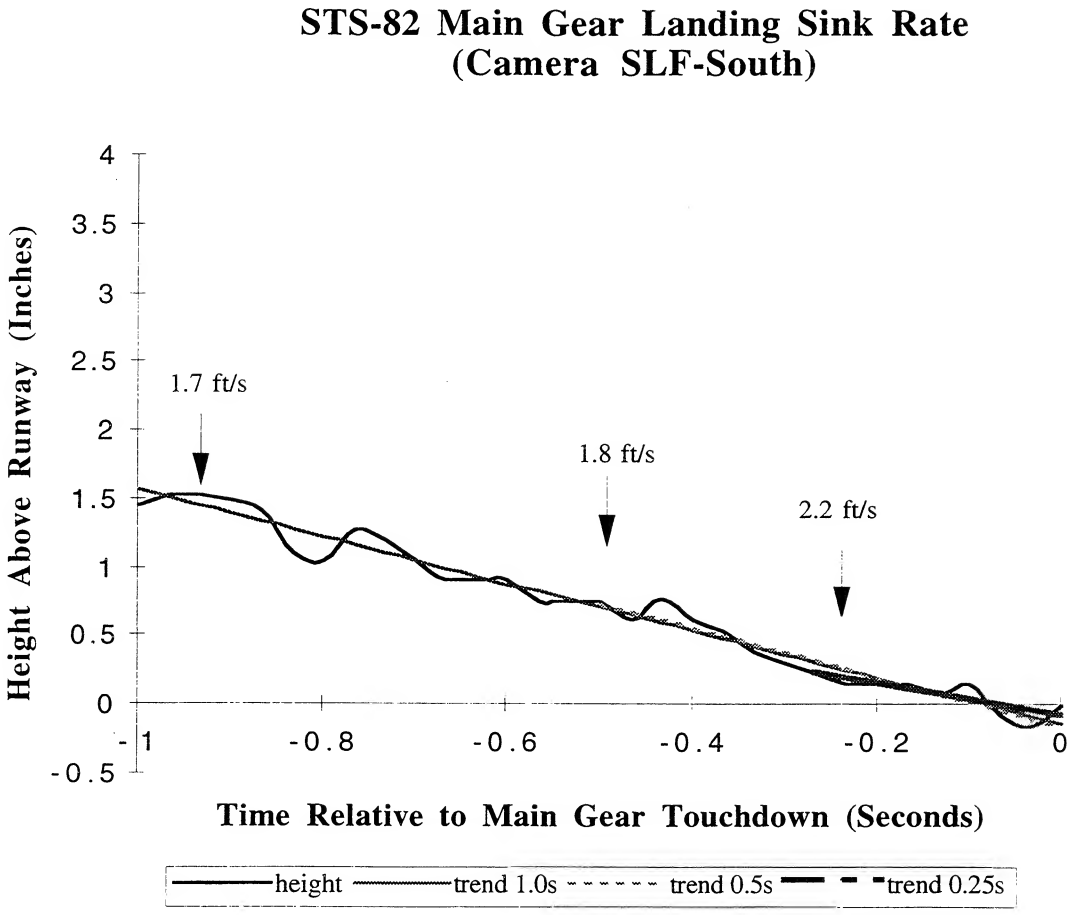

Figure 2.6.1 (A) Main Gear Height Versus Time Prior To Touchdown (Video)

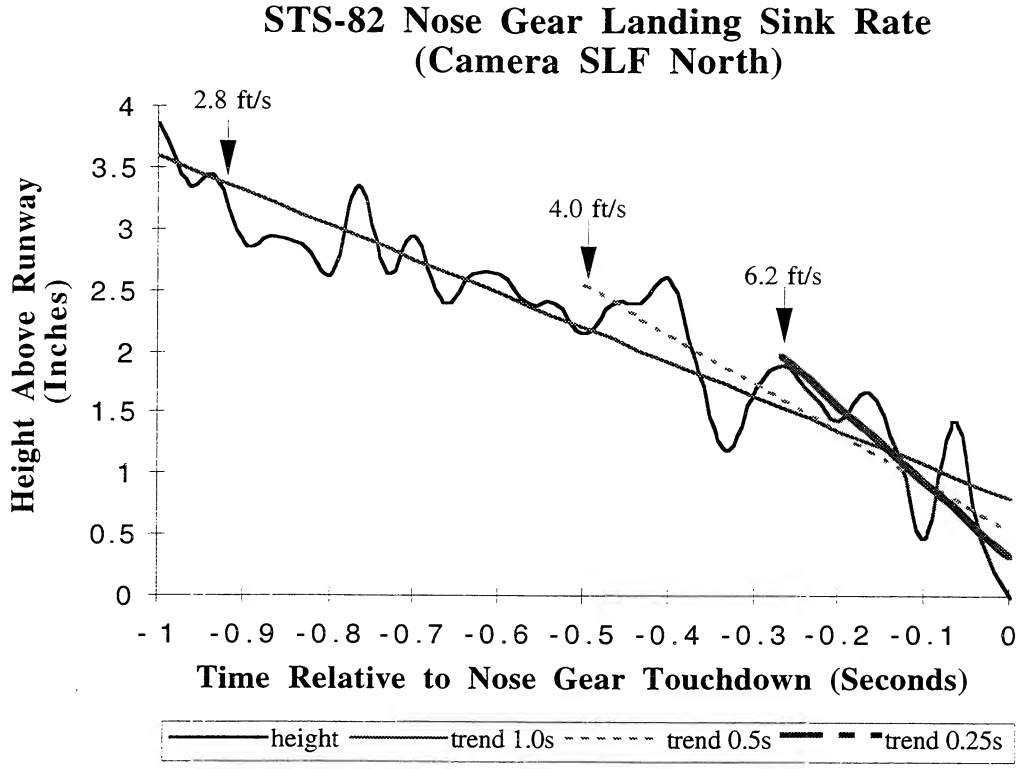

Figure 2.6.1 (B) Nose Gear Height Versus Time Prior To Touchdown (Video)

2.7 OTHER

2.7.1 Normal Events:

Other normal events observed included: ice and vapor from the ET/Orbiter umbilical areas during SSME ignition, inboard and outboard elevon motion at SSME ignition, ET twang, multiple pieces of light-colored debris falling from the LH2 and LO2 TSM T-0 umbilicals at disconnect, vapor and ice from the GUCP area during ET GH2 vent arm retraction, MLP debris at liftoff, acoustic waves during liftoff, debris in the exhaust cloud after liftoff, outgassing of the ET aft dome, vapor from the SRB stiffener rings after liftoff, roll maneuver, white flashes aft of the launch vehicle during early ascent, body flap motion, linear optical effect, ET aft dome charring, expansion waves, contrails from the Orbiter wing tips, SRB plume brightening prior to SRB separation, SRB separation, and slag debris after SRB separation.

2.7.2 Pad Events Observed Were:

Hydrogen ignitor operation, MLP deluge water activation, FSS deluge water operation, GH2 vent arm retraction, LH2 and LO2 TSM door closure, and sound suppression system water operation.

Loose tape-like material seen on the FSS during liftoff (Camera E54).

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Reply to Attn of: EP42 (97-015)

February 28, 1997

TO: Distribution

FROM: EP42/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-82

The launch of space shuttle mission STS-82, the twenty-second flight of the Orbiter Discovery occurred on February 11, 1997, at approximately 2:55 A.M. Central Standard Time from launch complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Photographic and video coverage has been evaluated to determine proper operation of the flight hardware.

The launch of STS-82 occurred during dark sky conditions. This reduces the amount of data received from photographic products. Tracking cameras only recorded the aft end of the vehicle. Darkness also reduced the ability to see the Solid Rocket Booster (SRB) holddown post Pyro Ignition Control (PIC) firing events. On-board coverage consisted of only hand-held photography by the astronauts. Twenty-nine images of good to fair quality were recorded with all portions of the External Tank (ET) imaged.

No anomalies were observed on film or video. The typical events were observed from film and video during launch and ascent of STS-82. These events include ice/frost falling from the 17 inch disconnects, debris particles falling aft (butcher paper, purge barrier material, and fire detection paper), debris induced streaks in the Space Shuttle Main Engine (SSME) plumes, linear optical distortions in the tracking imagery data, flow recirculation and glowing debris particles from the Solid Rocket Motor (SRM) plumes. Several tracking cameras recorded condensation vapors from the Orbiter's wing tips during ascent.

Several pieces of ice/frost fell from the LOX forward feedline bellows during SSME start and at liftoff. None of the pieces were seen to strike the Orbiter or cause any impact damage.

Ice was observed around the eyelid on ME-2 at liftoff. This type and amount of ice has been seen on previous launches.

The formation of the SSME mach diamonds was in the sequence of 2-3-1. This sequence is unlike the start sequence of 3-2-1. All other start events appeared to occur normally. The late mach diamond formation of ME-3 is believed to be a function of the ambient base pressure and has been observed on previous missions (STS-77, STS-73, STS-71, STS-60 and STS-59).

What appears to be debris induced streaks in the SSME plumes occurred at approximately T+39 seconds Mission Elapse Time (MET) as recorded by tracking camera E220 and E222. These streaks do not appear typical of paper debris due to their longer duration, nor do they appear to be streaks from the SSME's themselves due to their color and being visible in all three plumes.

Several tracking cameras recorded pieces of glowing debris particles exiting the SRM plume during ascent around T+71 seconds MET. The dark sky conditions enhanced the ability to see these particles during ascent.

The following event times were acquired.

EVENT	TIME (UTC)	DATA SOURCE
M-1 PIC Firing	08:55:17.026	Camera E9
M-2 PIC Firing	could not use	Camera E8
M-5 PIC Firing	08:55:17.026	Camera E12
M-6 PIC Firing	could not use	Camera E13
SRB separation	08:57:20.76	Camera E207

This report and additional information are available on the World Wide Web at URL:

http://photo4.msfc.nasa.gov/STS/sts82/sts82.html.

For further information concerning this report contact Tom Rieckhoff at 205-544-7677 or Jeff Hixson, Boeing North American at 205-971-3082.

Thomas J. Rieckhoff

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A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-82. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanned data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-82 and the resulting effect on the Space Shuttle Program.

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